

A GOLDEN STAMP BOOK

# ATOMIC ENERGY

The story of atomic energy today in industry, farming, medicine, and the space program — and how it may be used in the future. With 48 color stamps and line drawings on every page.



FUSION TAKES PLACE IN THE SUN



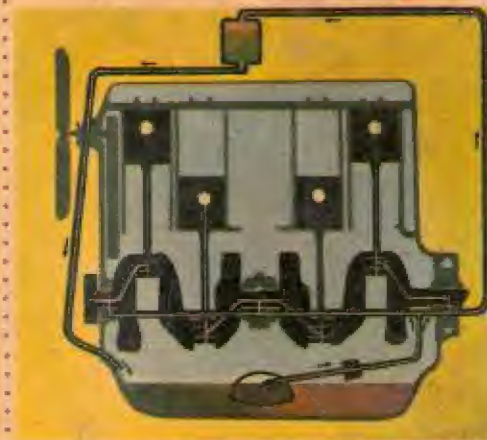
INSTALLING A REACTOR



NIKE ATOMIC ROCKETS



BOHR MODEL OF URANIUM ATOM



RADIOACTIVE OIL TRACER IN MOTOR



MAGNETIC BOTTLE

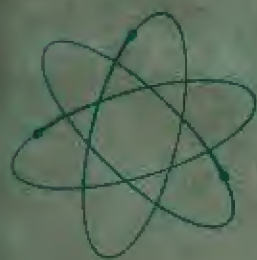


ATOMIC PLANT IN INDIA



REACTOR IN SUBMARINE





• GOLDEN STAMP BOOKS •

ATOMIC energy is a source of power far greater than any that mankind has known before. In this book you will learn how atomic energy was discovered, and how it is being used today for peaceful, constructive purposes. You will see and read about atomic power plants and how their reactors provide electricity for homes and industries; how radioisotopes are produced and used; and how atomic reactors supply power for ships such as the Nautilus, the submarine that traveled under the polar ice pack to the North Pole.

Text and pictures also show you the projects on which nuclear scientists are now at work. And finally you will see how atomic energy may someday help man reach neighboring planets.

To use this stamp book, first separate the gummed stamps. Then find the page where each stamp belongs and place the stamp in the space marked for it.







ATOMS RELEASE MORE ENERGY THAN FUELS



DEMOCRITUS' IDEA OF ATOMS



ONLY THE VERY HEAVY ATOMS FISSION



ATOMIC MERCHANT SHIP



CREATING NEW ELEMENTS FROM THE ATOM



CARNOTITE AND COBALT



GLOWING REACTOR CORE



TONS OF ORE YIELD OUNCES OF U-235



OIL RELEASED FROM SHALE BY ATOMIC BLAST



ATOMIC PLANT IN PENNSYLVANIA

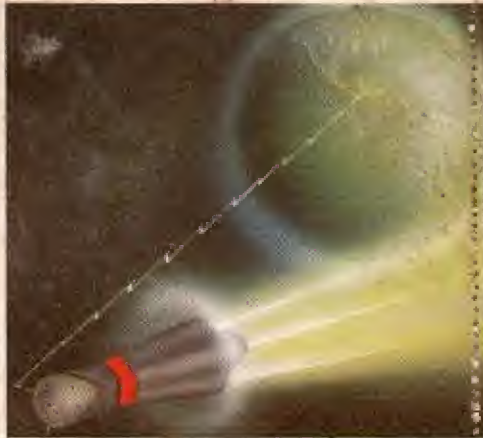


ATOMIC SUBMARINE UNDER NORTH POLE



ATOMIC PLANT IN ENGLAND





ATOMIC BATTERY USED IN SPACE PROGRAM



PATIENT GETTING RADIOCOBALT TREATMENT



RADIOACTIVE TRACER IN MOLECULE



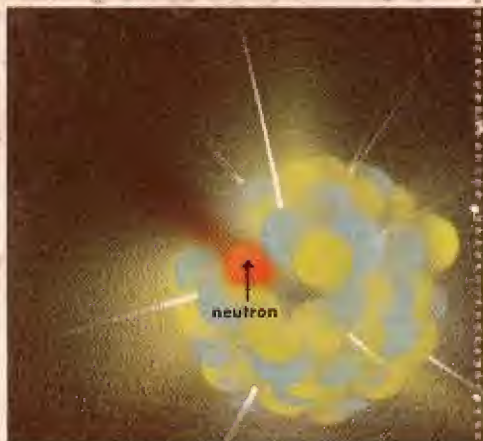
MODEL OF BREEDER REACTOR



HEAVY WATER HAS HEAVIER HYDROGEN ATOMS



TRACKS OF IONIZED ATOMS



THE URANIUM ATOM SPLITS



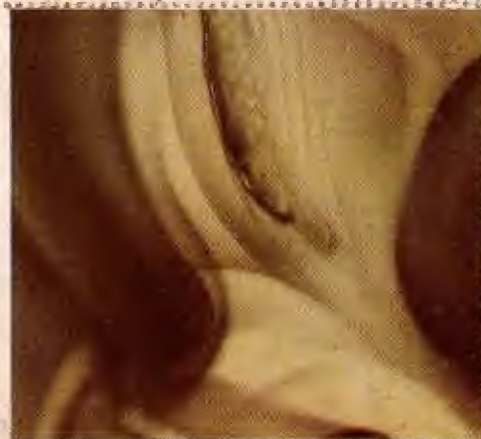
ATOMS FOR PEACE EXHIBIT



DISCHARGE OF IONIZED ATOMS



SINKING ATOMIC WASTES IN THE SEA



GAMMA RAYS SHOW DEFECTS IN STEEL



SCIENTISTS DOING RESEARCH ON THE ATOM





VAN DE GRAAFF ATOM SMASHER



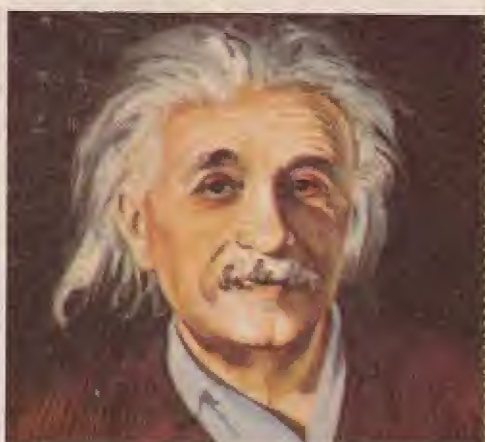
TESTING ATOMIC ROCKET MOTOR



ATOMIC-POWERED SPACESHIP



CYCLOTRON



ALBERT EINSTEIN



UNDERWATER HYDROGEN BOMB TEST



THE SEA IS A SOURCE OF HEAVY HYDROGEN



AN ATOMIC PILE



ATOMIC AGRICULTURE



SHIELDED ROBOT DEVICE



FUSION RELEASES MORE ENERGY THAN FISSION

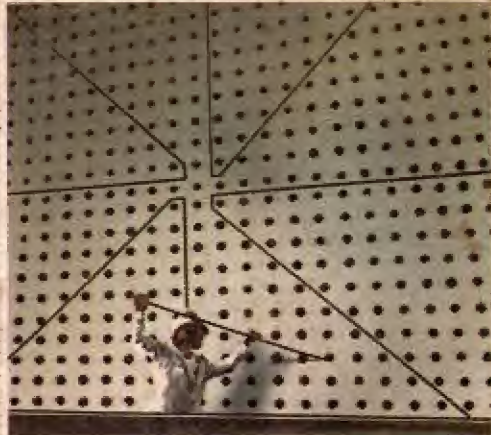


STERILIZING FOOD BY RADIATIONS





THE DISCOVERY OF RADIUM



RODS IN REACTOR CONTROL CHAIN REACTION



FUSION TAKES PLACE IN THE SUN



WORKING WITH RADIOISOTOPES



ATOMIC BOMB TEST



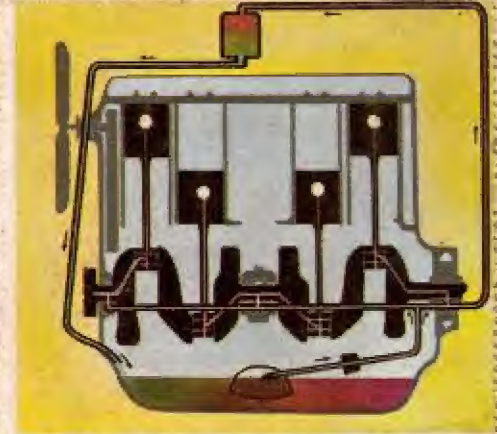
INSTALLING A REACTOR



NIKE ATOMIC ROCKETS



BOHR MODEL OF URANIUM ATOM



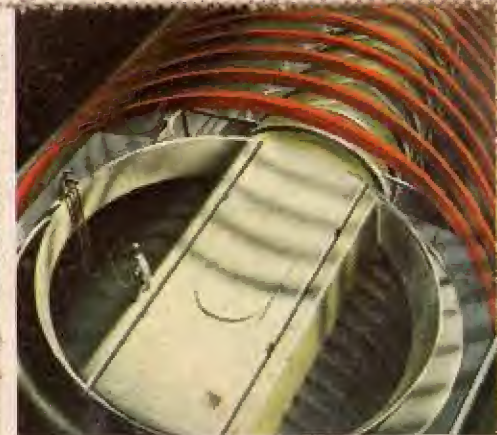
RADIOACTIVE OIL TRACER IN MOTOR



MAGNETIC BOTTLE



ATOMIC PLANT IN INDIA



REACTOR IN SUBMARINE



A GOLDEN STAMP BOOK

# ATOMIC ENERGY

By OTTO BINDER

Color Illustrations by GEORGE SOLONEVICH

Black and White Drawings by MIKE STRAUSS

Here is a list of the stamps, with the pages on which they should be placed.

Albert Einstein	4	Model of Breeder Reactor	27
An Atomic Pile	8	Nike Atomic Rockets	14
Atomic Agriculture	37	Oil Released from Shale	
Atomic Battery Used		by Atomic Blast	45
in Space Program	41	Only the Very Heavy	
Atomic Bomb Test	9	Atoms Fission	15
Atomic Plant in England	30	Patient Getting	
Atomic Plant in India	31	Radiocobalt Treatment	35
Atomic Plant		Radioactive Oil	
in Pennsylvania	29	Tracer in Motor	36
Atomic Merchant Ship	44	Radioactive Tracer	
Atomic-powered Spaceship	47	in Molecule	39
Atomic Submarine		Reactor in Submarine	42
under North Pole	43	Rods in Reactor	
Atoms for Peace Exhibit	32	Control Chain Reaction	26
Atoms Release More		Scientists Doing	
Energy than Fuels	24	Research on the Atom	48
Bohr Model of Uranium Atom	1	Shielded Robot Device	34
Carnotite and Cobalt	23	Sinking Atomic	
Creating New Elements		Wastes in the Sea	16
from the Atom	13	Sterilizing Food	
Cyclotron	12	by Radiations	38
Democritus' Idea of Atoms	2	Testing Atomic	
Discharge of Ionized Atoms	10	Rocket Motor	46
Fusion Releases More		The Discovery of Radium	3
Energy than Fission	18	The Sea Is a Source	
Fusion Takes Place		of Heavy Hydrogen	22
in the Sun	17	The Uranium Atom Splits	6
Gamma Rays Show		Tons of Ore Yield	
Defects in Steel	40	Ounces of U-235	7
Glowing Reactor Core	25	Tracks of Ionized Atoms	5
Heavy Water Has		Underwater Hydrogen	
Heavier Hydrogen Atoms	20	Bomb Test	19
Installing a Reactor	28	Van De Graaff Atom Smasher	11
Magnetic Bottle	21	Working with Radioisotopes	33

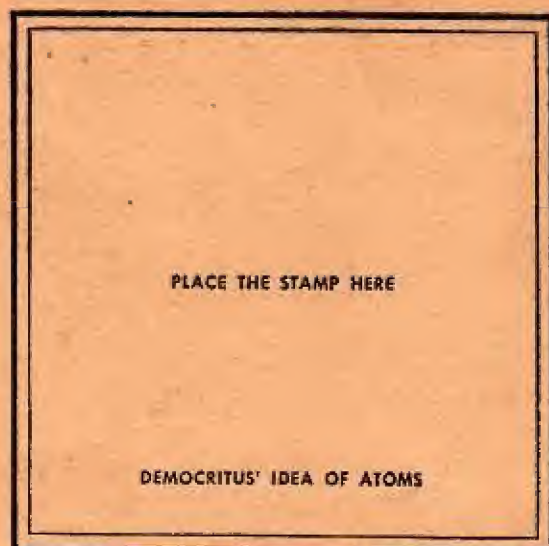
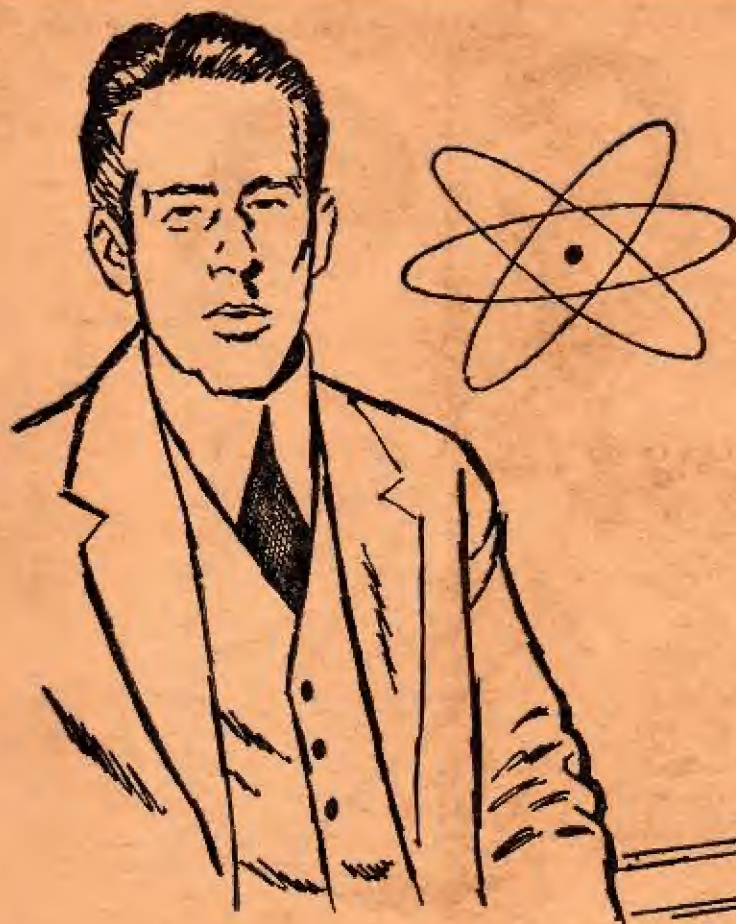
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BOHR MODEL OF URANIUM ATOM

GOLDEN PRESS  NEW YORK

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Niels Bohr described the atom as being mainly empty space.



## The Beginning

In Greece, about 600 B.C., a philosopher named Thales first proposed the idea that all objects were made up of tiny bits of matter which could not be broken up into any smaller units. These bits were named atoms, a word meaning "cannot be divided."

A century later, also in Greece, a philosopher named Democritus drew sketches of atoms, which he imagined as being of many different sizes and shapes.

In 1803, John Dalton, an English chemist, gave a more scientific description of atoms. He said they had round shapes. He also said that, though their sizes were about the same, their weights were very different.

Other scientists agreed and eventually listed exactly 92 kinds of atoms that made up 92 different elements, or substances that

could not be changed into other substances. These basic atoms combine to form millions of kinds of molecules—groups of atoms—which make up all the substances we know.

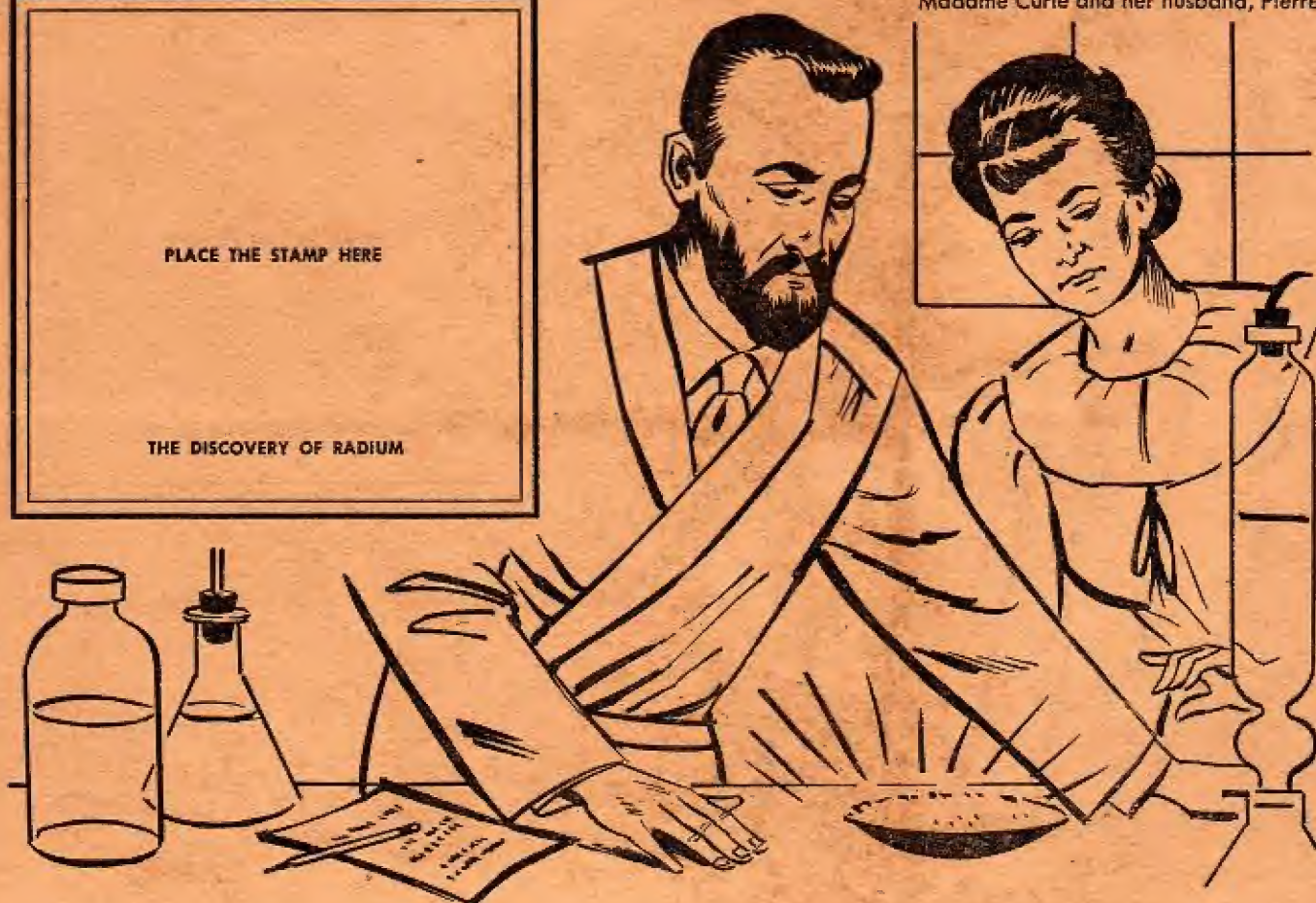
But Dalton believed the atoms were solid. This concept changed at the end of the 19th century when the electron was discovered. Later Niels Bohr of Denmark drew models of atoms showing that they were mostly empty space. Electrons revolved around heavy, little protons in the nucleus, like planets around a sun. In the lightest element, hydrogen, only one electron circles one proton. The heaviest natural atom, uranium, has 92 electrons circling a group of nucleus particles.

This is the picture of the atom that science follows today.





Madame Curie and her husband, Pierre



## The Discovery of Radium

Until 1898, it was thought that no element's atoms could change into another element's atoms. Then Becquerel discovered that uranium breaks up spontaneously. Later Madame Curie, a brilliant woman scientist, discovered the radioactive element radium. Radium gave off heat and also radiations called alpha, beta, and gamma rays.

Further study proved the alpha rays were streams of high-speed helium ions, the beta rays were electrons, and the gamma rays were pure energy waves. Madame Curie suggested the name "radioactivity" for this process, which was caused by the radium atoms' breaking down to form lead atoms.

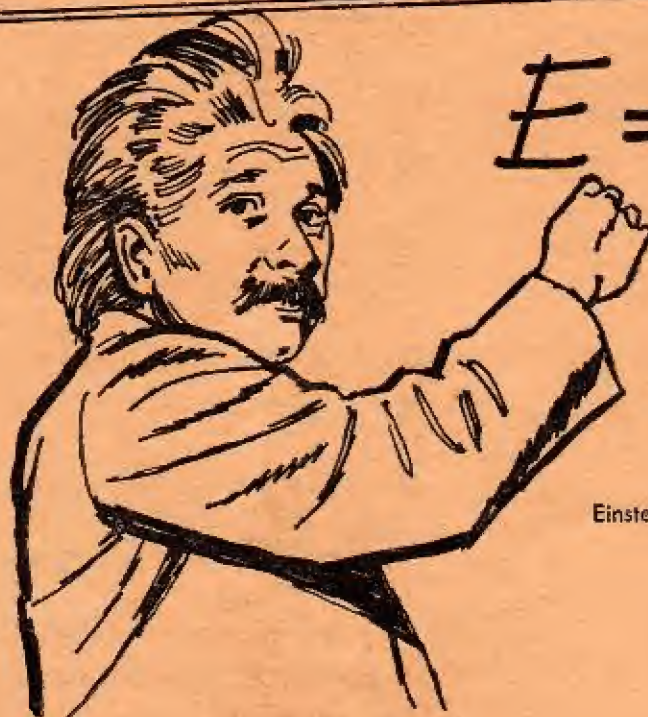
It was therefore not true that elements never changed. Other heavy elements such as radon (#86), actinium (#89) and thorium

(#90) also proved to be "unstable," by constantly breaking down.

A fixed rule of radioactivity is that half of any radioactive element will change to another element in a certain period of time. In the case of radium, half of it will change in 1,700 years; half of what is left will change in the next 1,700 years, and so forth. The time it takes for this change is called the element's *half-life*. Each radioactive element has a different half-life.

Each speck of radioactive elements gives off an enormous amount of energy. Radium first gives off helium ions followed by electrons. In this process of breaking down to lead, some of the nuclei that are formed give off gamma rays which are much more powerful than X-rays.





$$E = mc^2$$

Einstein's formula says that matter can turn into energy.

## Einstein's Formula

Radioactivity brought up two questions. As radium broke down, the combined product of the decay lost mass. How could solid matter vanish? And where did the great energy come from?

In 1905, Albert Einstein found the answer when he said the lost mass caused the great energy. His famous formula,  $E = mc^2$ , says that matter can turn into energy.

And this lost mass created a very large amount of energy, far more than that obtained from burning coal, oil, or from explosives like TNT. In fact, scientists concluded from Einstein's formula that weight for weight, radioactivity was more than a million times greater than any other kind of power we knew.

But it was not easy to release this energy locked up within the heart of the atom. Scientists tried but failed in their attempts to speed up radioactivity and to make more radium

atoms burst apart. Nor could they slow the radioactivity down either. There seemed to be no way to change the natural process of radioactivity. For many years, nobody could find a way to tap the energy within the mighty atom, even though scientists knew it was there.

PLACE THE STAMP HERE

ALBERT EINSTEIN



## Inside the Atom

Meanwhile, chemists were puzzled as to why atoms weighed more than they should. The theory was that for every circling electron with a negative charge, there must be one nucleus proton with a positive charge. Why then did helium, with only two electrons, have an atomic weight four times that of hydrogen? Hydrogen, the simplest atom, has one proton and one electron. If there were four protons in the nucleus of helium, why weren't there four circling electrons?

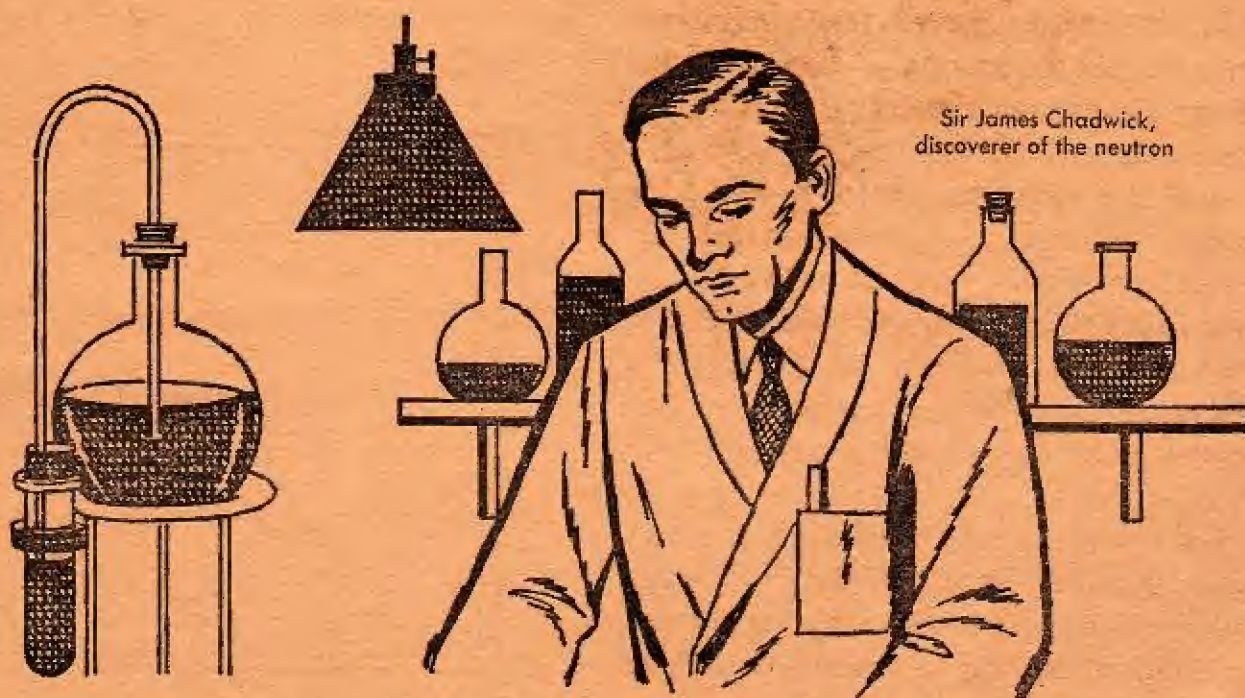
Other elements were equally puzzling. Uranium, for instance, with 92 electrons, had an atomic weight of 238. That meant its nucleus held 146 extra protons, which was impossible. Something was wrong with the scientists' picture of the atom's core.

In 1932, Sir James Chadwick of England and Joliet-Curie and his wife in France found the answer when they determined the exact nature of the neutron. This was a particle equal in weight to a proton, but neither negatively nor positively charged. Therefore, any neutrons in the nucleus did not require



any orbiting electrons to balance the electrical charges of the whole atom.

That explained helium which had the atomic weight of 4. It had two protons plus two neutrons in its nucleus. Yet it needed only two electrons. And uranium had only 92 protons for its 92 electrons, plus 146 extra neutrons. That cleared up the riddle of the overweight atoms and gave scientists a new picture of the atom's inner core.



Sir James Chadwick,  
discoverer of the neutron



## The Atom Splits

The neutron was the key which unlocked atomic power.

Previously, nuclear scientists had tried to use high-speed protons to smash atoms apart, but these protons were repelled by the protons in the atom's nucleus. According to the laws of electricity, like charges repel each other, and all protons are positively charged.

But the neutron, which has no electric charge, might be sent straight into a nucleus. Various scientists had tried this but had obtained puzzling results.

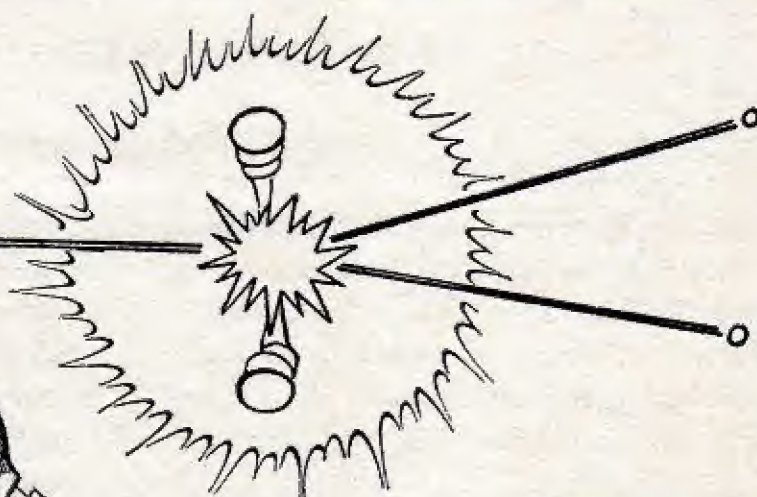
In 1939 two scientists working in Germany—Otto Hahn and Fritz Strassmann—shot neutrons into uranium atoms, splitting them with a great release of energy. Lise

Meitner, the great woman physicist, suggested to Niels Bohr of Denmark that the result of this was uranium fission. This was proved to be true. Atomic energy had been achieved at last.

When World War II broke out, nuclear scientists working in the United States realized that uranium fission might be used as a military weapon. They wanted this country to win the race in getting such a weapon. Finally, with Einstein acting as spokesman, they appealed to President Roosevelt.

Within a few years several atomic projects had been launched in the United States. One of these was the Manhattan Project which started the first nuclear chain reaction.

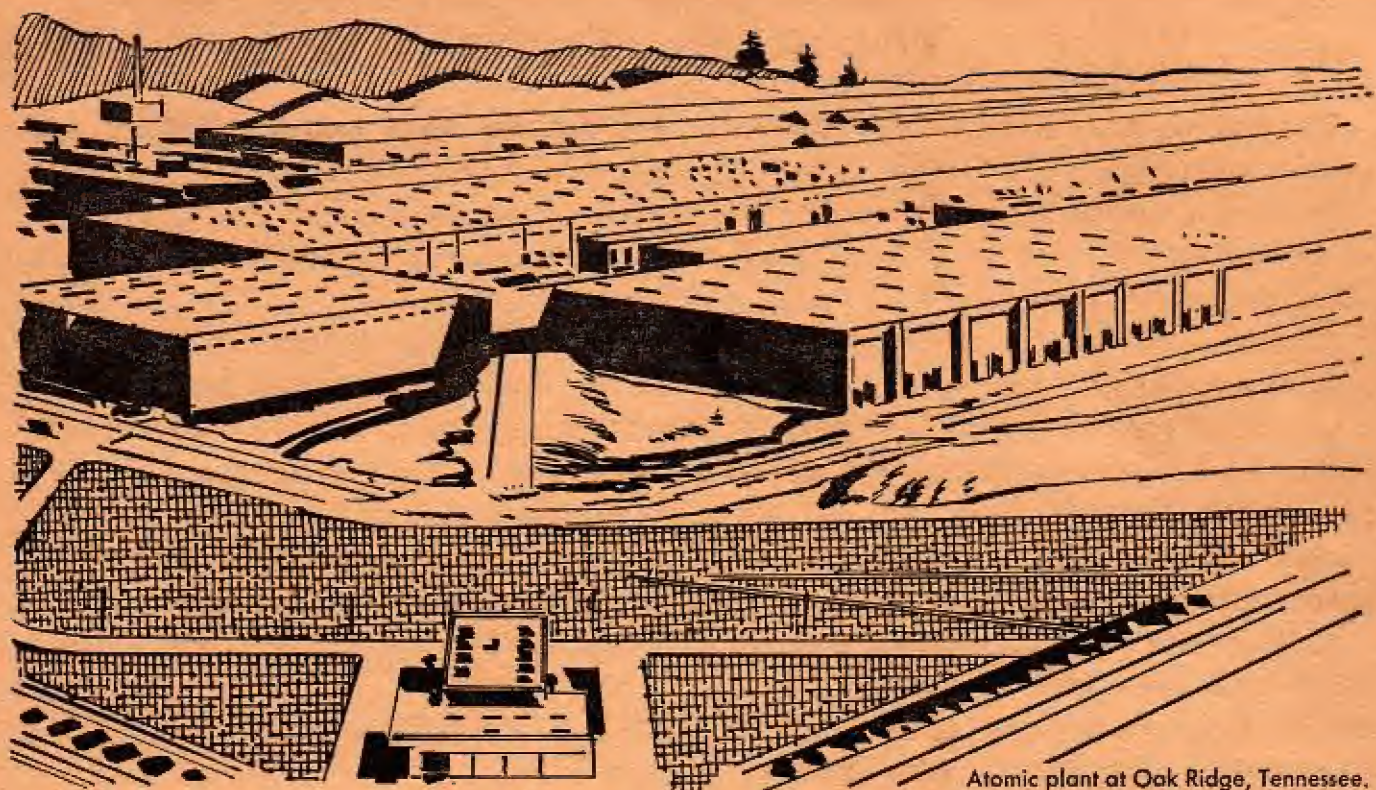
Otto Hahn and Fritz Strassmann  
split uranium atoms.



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THE URANIUM ATOM SPLITS





Atomic plant at Oak Ridge, Tennessee.

## The Manhattan Project

Beginning in 1940, two billion dollars were poured into the program to make the atomic bomb. Among the scientists working on this project were twenty Nobel Prize winners in science. They faced a hard task.

First, they had to find out how to release atomic energy in large amounts. Previously a few dozen uranium atoms had been split.

Now atoms had to be split by the trillions to get worthwhile amounts of atomic power.

Also, at that time, uranium was a scarce metal. Ores had to be shipped in from such faraway places as the Belgian Congo in Africa. A plant was built at Oak Ridge, Tennessee, to work the ores and produce purified uranium in far greater amounts than had ever existed before.

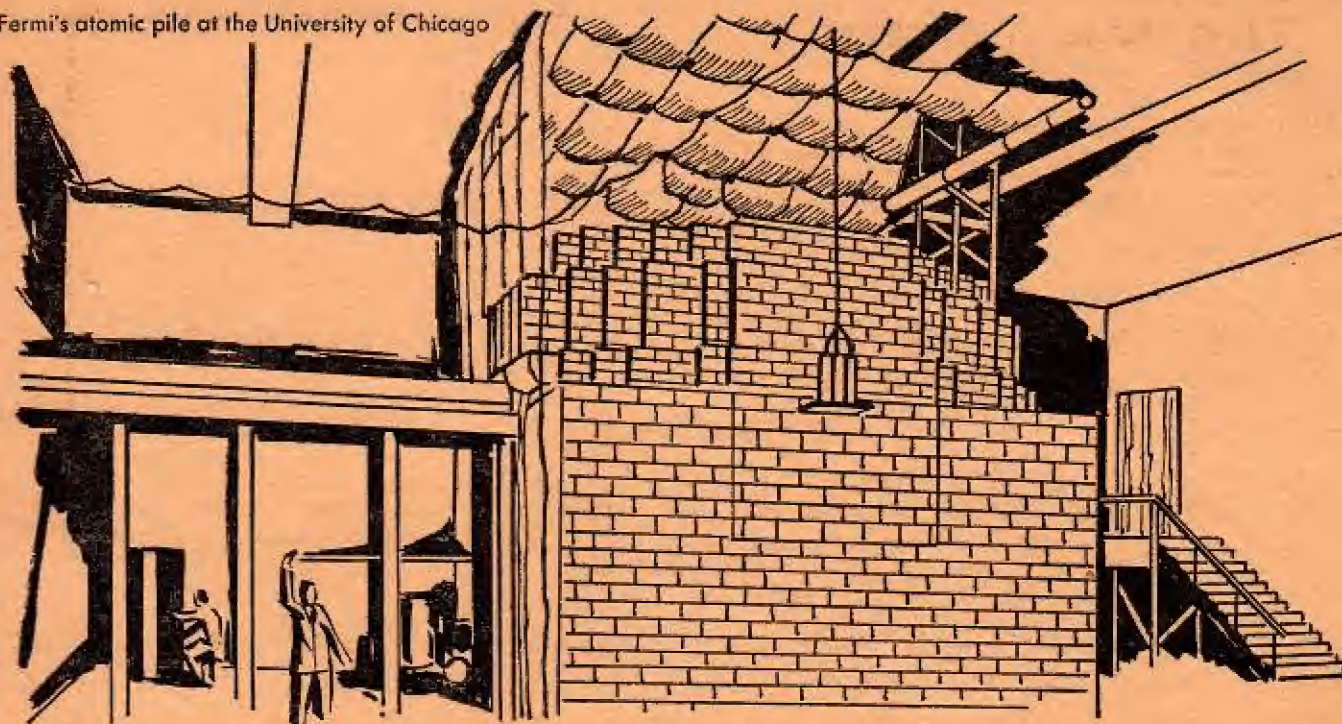
This was necessary because ordinary uranium is a mixture of two atoms of different atomic weights. These are called U-238 and U-235. All uranium is radioactive but only U-235 is fissionable by neutrons. And U-235 was less than one percent of the total refined metal. So, many tons of uranium were needed in order to secure a few pounds of U-235, which could produce atomic energy.

It took more than two years to produce the uranium needed, as well as other special products including graphite and zirconium metal, to make an atomic pile.





Fermi's atomic pile at the University of Chicago



## The First Atomic Pile

On December 2, 1942, in a laboratory at the University of Chicago, the atomic scientist Enrico Fermi put up his hand for a signal. He was the chief of the project at Chicago.

His staff had built an atomic pile, 15 feet long and 15 wide, by piling up bricks of graphite and pure uranium. The metal alone totaled 500 tons.

The outside surface of the pile was punched with many holes through which cadmium rods extended into the core. These were control rods that could absorb neutrons given off by the radioactive U-235. As Fermi signaled, his men slowly pulled the rods out, allowing neutrons to fly all around through the core. The graphite acted as a moderator to slow down the neutrons that pierced it. The slower the neutrons went, the more chance they had of striking uranium nuclei.

More and more neutrons in the atomic pile began to smash uranium atoms. But now thousands of atoms were being split . . . then



millions . . . then countless billions. The needle of a power gauge swung up. It finally passed a red line. Now atoms were splitting faster than in any natural radioactive element.

It was a big moment, for the atomic pile had "gone critical." That meant, for the first time in history, that a chain reaction had been started. Thirty-seven years after Einstein's formula had showed the way, scientists had unlocked atomic power.



# The Atom Bomb

Fermi had released atomic energy, but it took another two years to make an atomic bomb. This called for a fissioning fuel that would release its energy in one blast instead of slowly as the fuel did in the atomic pile.

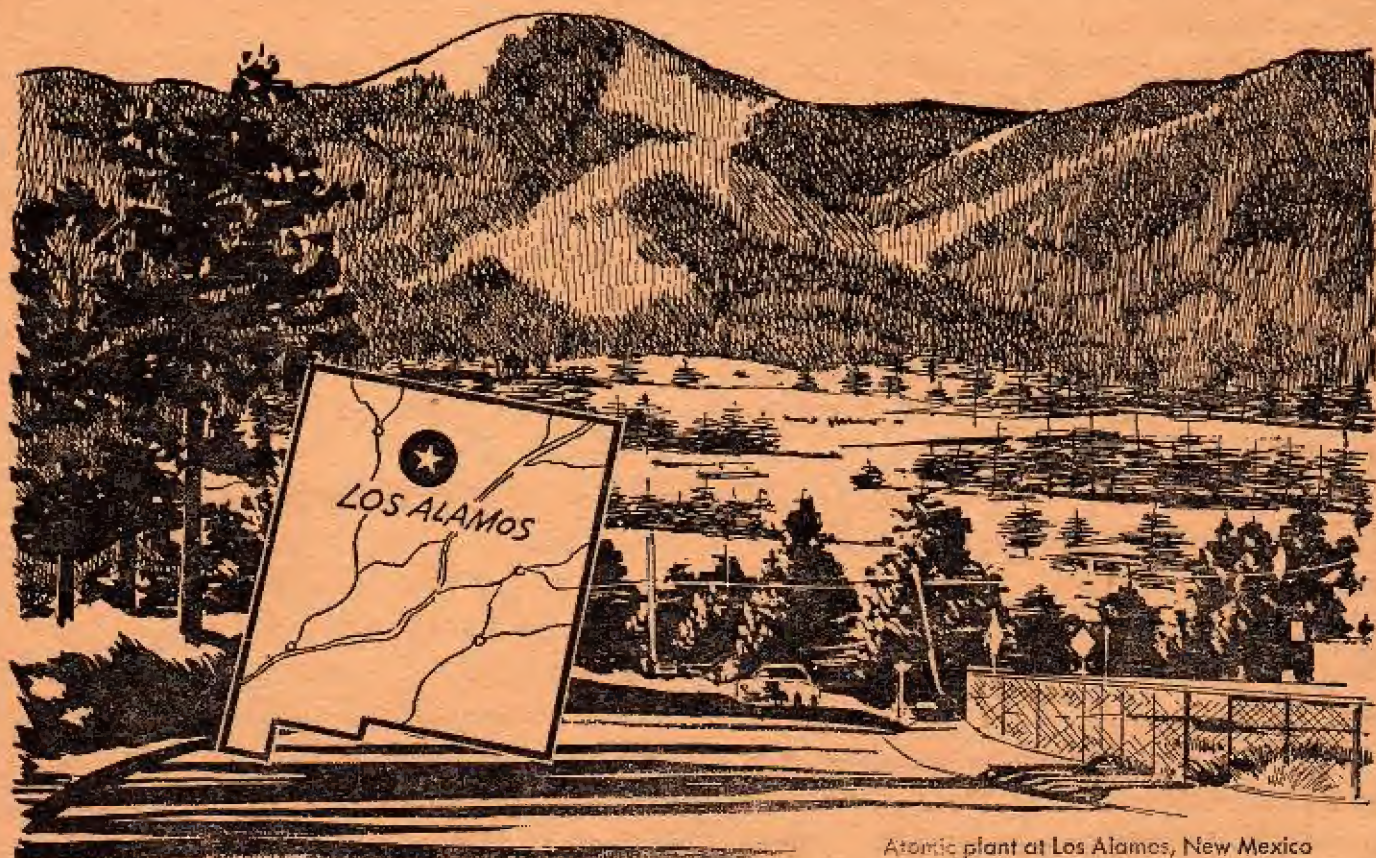
One such fuel was found in the core of the first atomic pile. It was a new element called plutonium, Pu-239. It had been created by changing radioactive uranium atoms.

Plutonium was an artificial element that had never existed on the earth. It had been produced before only in scientific experiments. Atomic piles were built to produce plutonium. Nuclear calculations showed that a racing chain reaction could explode it.

Meanwhile, atomic plants had purified another fuel, U-235, for a bomb. To "go critical," a certain exact amount of U-235 was required. Less than that "critical mass" would not explode. Scientists had to invent a

device that would jam several pieces of U-235 together with clockwork precision to make an explosion.

In July, 1945, at Los Alamos, New Mexico, the first atomic bomb in history was exploded. The great fireball mushrooming in the sky proved that one atomic bomb had more power than 10,000 tons of TNT.



Atomic plant at Los Alamos, New Mexico



## The AEC

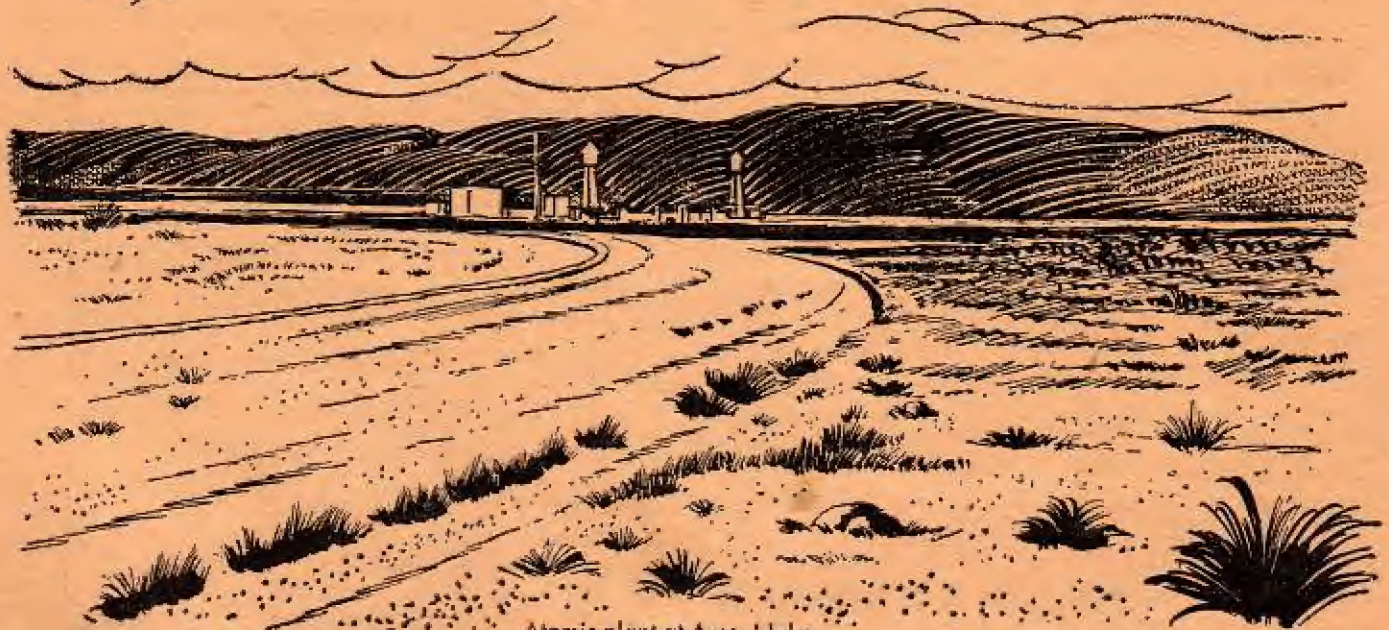
On August 6, 1945, the first atomic bomb was used in the war against Japan, destroying half of the city of Hiroshima. On August 9, the second atomic bomb was dropped on Nagasaki. No more atomic bombs were used. Japan surrendered on August 14, 1945.

Now research into the peaceful uses of atomic energy could be started. The Atomic Energy Commission was formed in the United States on August 1, 1946, to explore all the ways of using atomic power for peaceful purposes. The clumsy atomic piles were not built anymore; they were replaced by smaller and more useful reactors. The atomic cores of the reactors used only a few tons of uranium and gave more power than the 500-ton atomic pile.

Many experimental reactors were designed, in an effort to find better ways to harness atomic power so it could be used to run machines. Under the research program of the AEC, in December, 1951, the reactors of the Arco Atomic Plant, in Idaho, produced the first experimental electricity in the world to come from the atom.

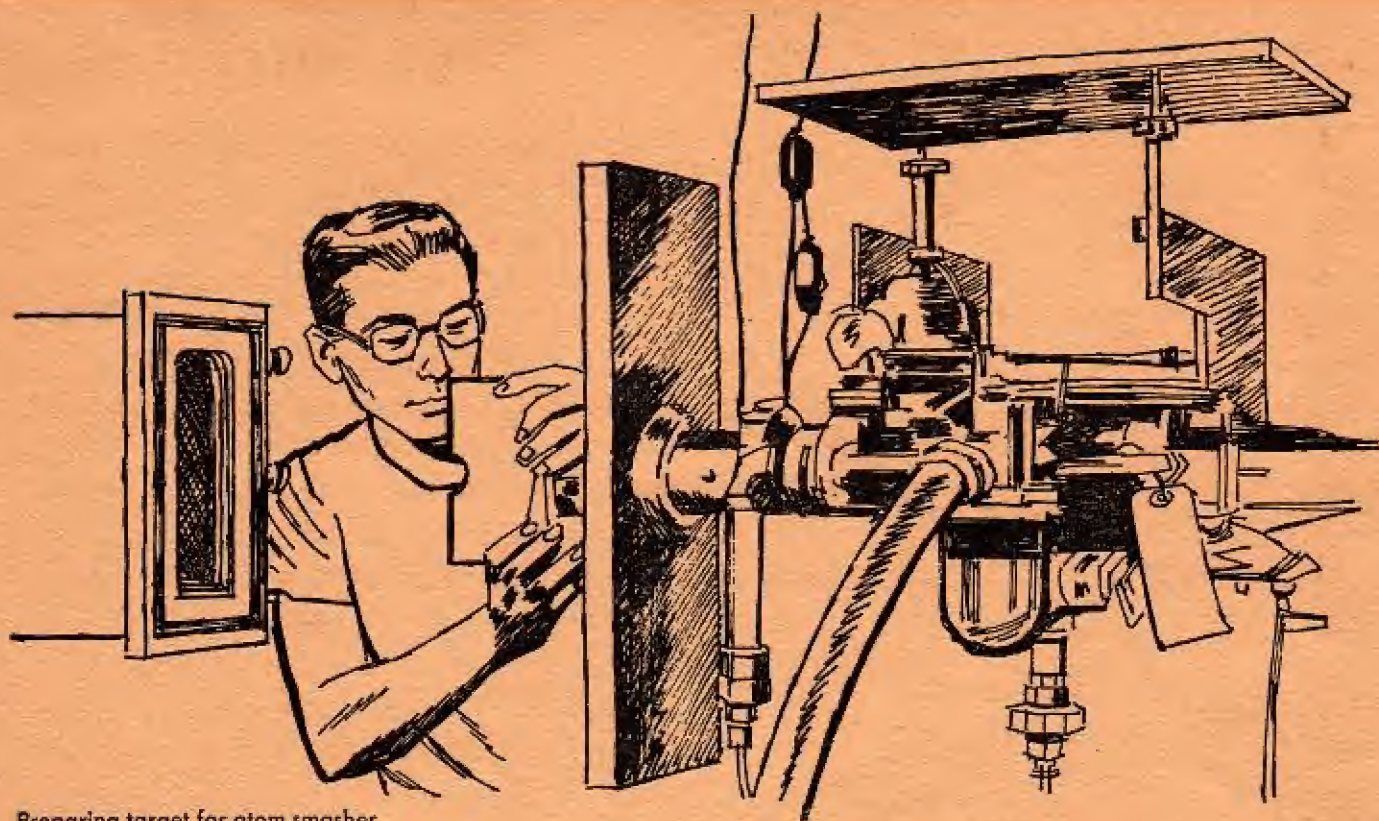
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DISCHARGE OF IONIZED ATOMS



Atomic plant at Arco, Idaho





Preparing target for atom smasher

## The Atom Smashers

Nuclear scientists had begun atom-smashing on a small scale long before the day of the atomic reactors. They unlocked some of the innermost secrets of the atom.

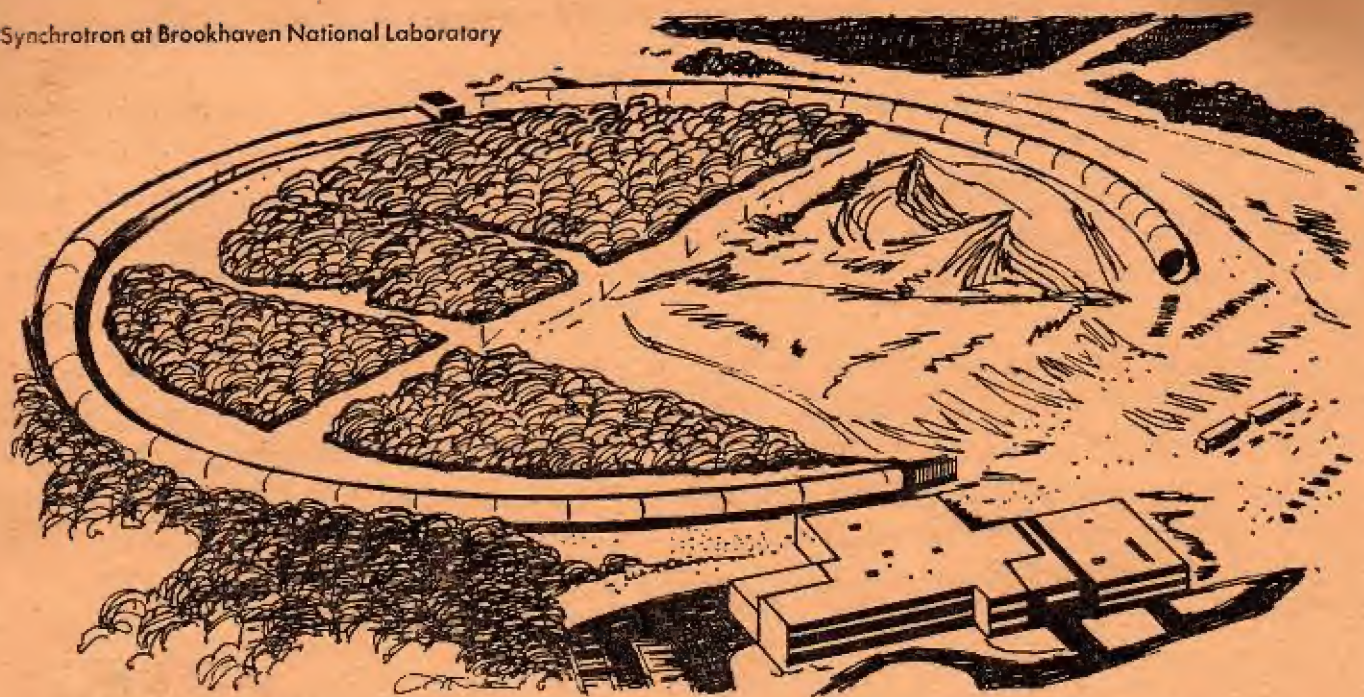
In the early 1930's, Ernest O. Lawrence, of the University of California, perfected the cyclotron. It was shaped like a large, covered frying pan. The air was pumped out of the cyclotron to leave a partial vacuum, and protons were sent in through a central opening. A powerful magnetic field then made the protons spiral outward in a widening circle. They gained speed as an alternating electrical coil gave the particles a "push" each time they went around.

The cyclotron could make the particles gain speeds of thousands of miles a second, faster than anything except light waves. This high speed gave the protons great energy. These speeding protons were then let out of a slit to strike a target, such as metal foil, and to smash its atoms.

The smashing of the atoms gave added proof to the scientists that atomic nuclei were not solid but were composed of groups of tightly packed protons and neutrons. And the smashing of atoms also created and released previously unknown particles. Nuclear scientists were now able to get a clearer picture of the mysterious heart of the atom.







## More Atom Smashers

Lawrence's first cyclotron was only a few feet wide and produced 80,000 electron-volts. An electron-volt is the energy one electron gains when it is acted on by one volt in the electrical field through which it moves.

Bigger atom-smashing machines were built. Today, there is a giant bevatron, 140 feet in diameter, which is producing six billion electron-volts. A synchrotron is now being built that is 700 feet wide and will produce up to thirty billion electron-volts.

Bevatron, synchrotron, and cosmotron are names for the new atom-smashing machines. They work differently but they all do the same job—smashing atoms apart. With these machines scientists have found that the nuclei of atoms are much more complex than they first thought. This may help to explain the mystery of why such great energy comes out of such tiny bits of matter.

When the protons and neutrons are smashed apart, in the nucleus of most atoms, other subatomic particles called mesons are released. A dozen or more kinds of these par-

ticles exist. They are called mu-mesons, pi-mesons, theta-mesons, and so on. They are thought to be the source of the powerful binding force that holds together the many parts of the nucleus.

Altogether, 21 or more different kinds of particles are now known to come out of the nuclei of atoms. Some seem to be created only when nuclei are smashed. The list will probably keep growing:





## Artificial Atoms

The first atomic pile created large amounts of two new elements, neptunium and plutonium, each heavier than uranium in atomic weight. These are called the trans-uranium elements. They are synthetic elements, made by man.

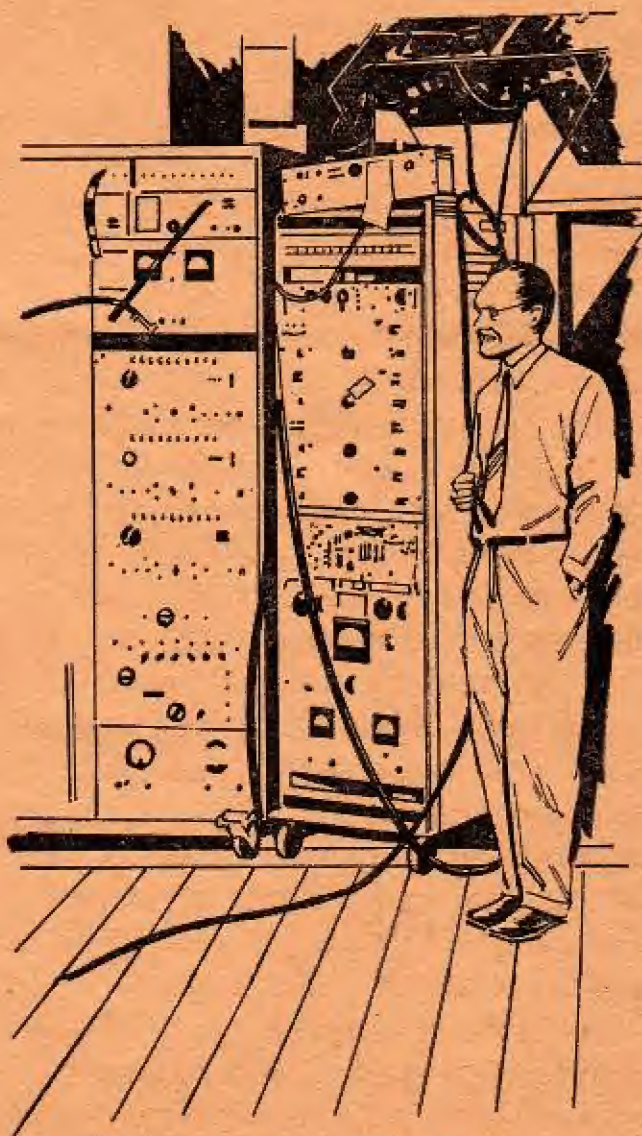
Glenn T. Seaborg, a member of Lawrence's staff, then began "discovering" more new elements by creating them, extending the atomic table from #95 to #102. He used a cyclotron to fire protons and neutrons into plutonium, #94, until it was built up into the heavier atoms of #95. Then he built up #95 into #96, and so forth. Each time he added one proton and several neutrons he had a new element.

The international committee for naming new elements called #95 americium to honor America for giving the world atomic energy. Then #96 became curium to honor Madame Curie, who discovered radium. In honor of Seaborg and Lawrence, #97 became berke-  
lium, after their city of Berkeley, while #98 became californium for their state.

Elements #99 and #100 were named einsteinium and fermium in honor of Einstein and Fermi. Mendelevium, #101, is

named for Mendeleev, the Russian chemist who first fitted all elements into the atomic table back in 1869. Finally, #102 became nobelium, named after the donator of the famous Nobel Prizes.

Of the ten new elements beyond #92, or uranium, all, except for plutonium and neptunium, have been made only in tiny amounts. They are so radioactive that they break down almost immediately. Element #103 and others beyond will probably also be created as time goes on.



Artificial radioactive elements have been created by scientists in laboratories.

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CREATING NEW ELEMENTS FROM THE ATOM



## Post-War Atomic Tests

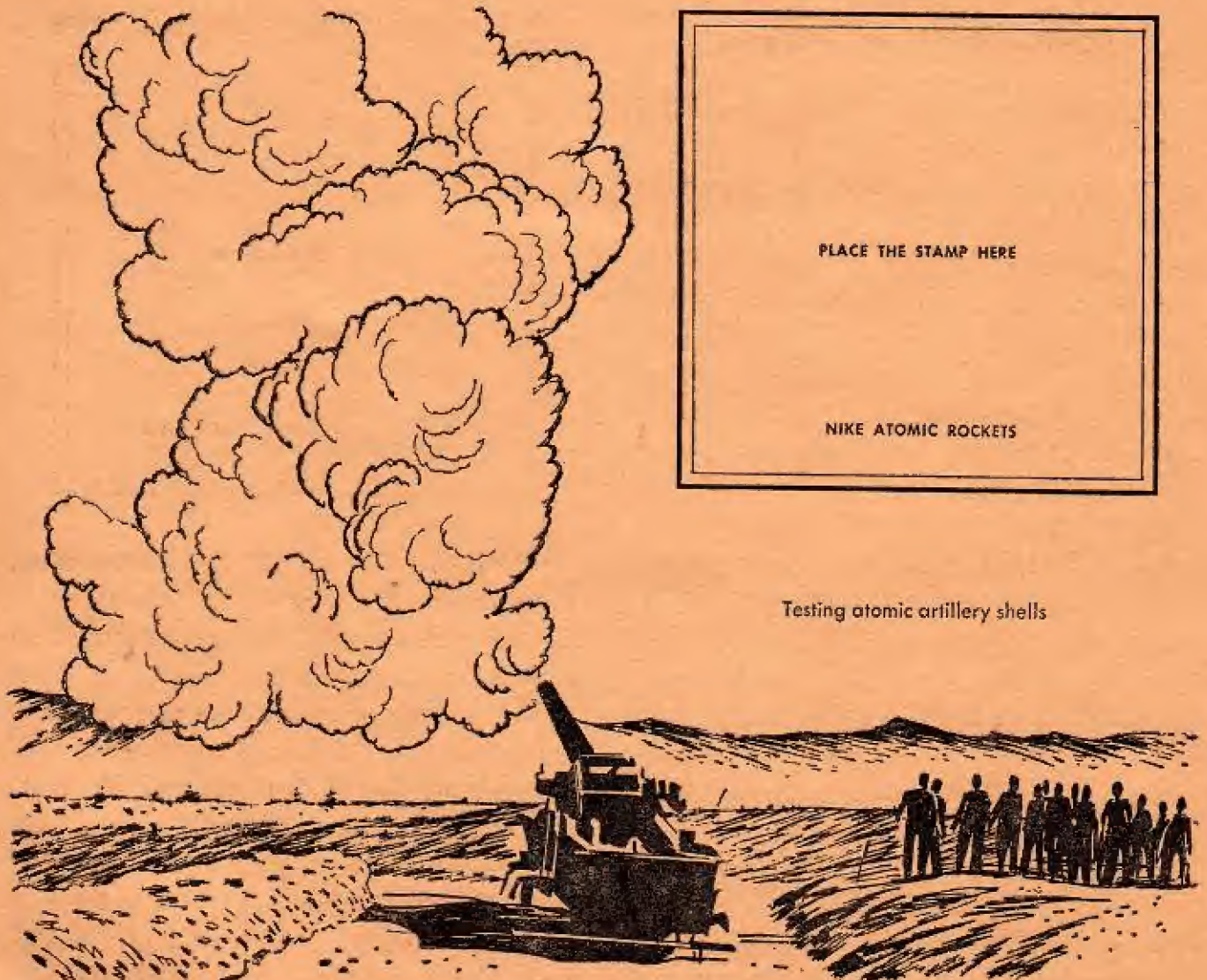
After the war, the United States continued to make atomic bombs for national defense. Atomic tests were carried out in the Pacific Ocean among uninhabited or evacuated islands.

The power of atomic bombs was rated by the *kiloton*, which is equal to 1,000 tons of TNT. The Los Alamos bomb was of 10 kilotons power—equal to 10,000 tons of TNT. Bombs of twice that power, or 20 kilotons, were used in 1946. Exploding in the air, one of these bombs sank five out of ninety old warships anchored in Bikini Lagoon and used as targets. The rest of the warships were

badly damaged. Later, an underwater bomb sank eleven ships and hurled the rest of the ships on the beach as wreckage.

The power of atomic bombs being made rose to 120 kilotons by 1948, to 250 kilotons in 1951, and finally to 500 kilotons by 1953. These giant atomic bombs were equal to fifty of the type of bomb used at Los Alamos.

Smaller bombs were also developed for tactical, or small target purposes. Their power ranged from 5 to 25 kilotons. These were small enough to be packed into shells, or to be used as warheads for short range rocket missiles.

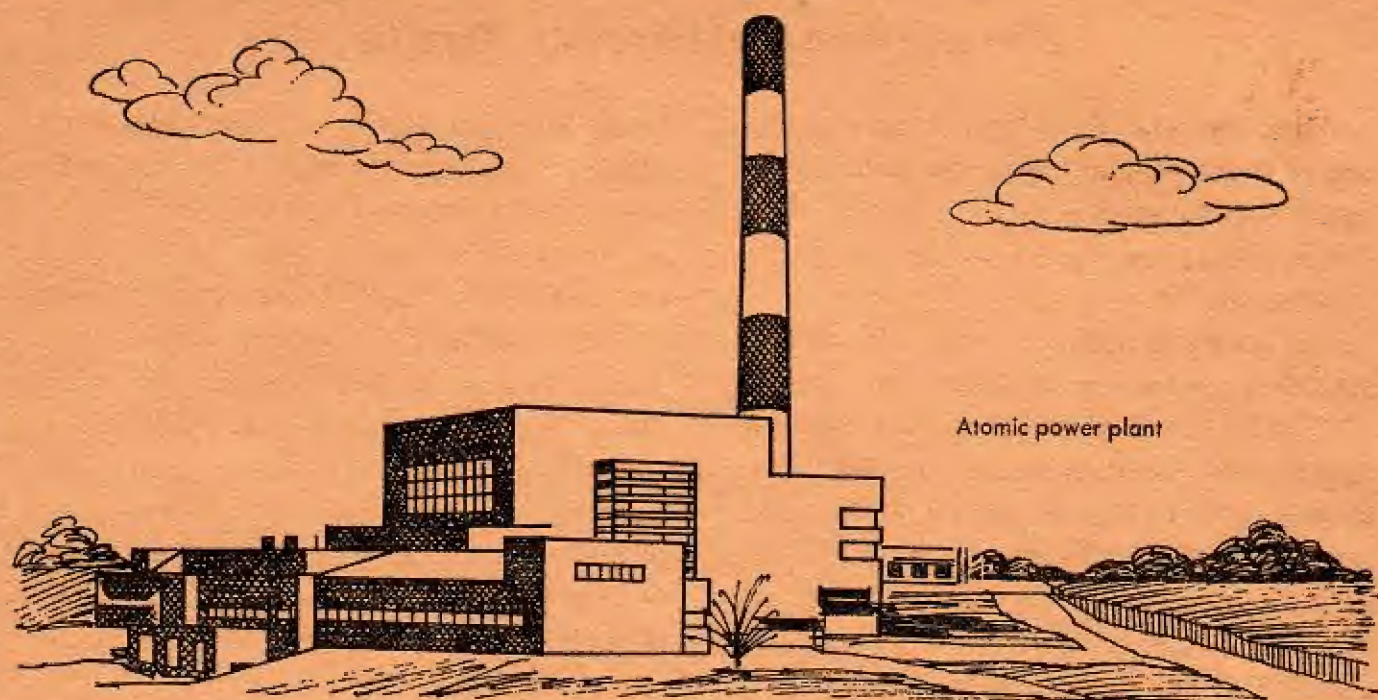


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NIKE ATOMIC ROCKETS

Testing atomic artillery shells





## Nuclear Myths

The general public had some needless fears about the atomic bomb. One such fear was that a very big atomic bomb would start a chain reaction in the earth itself and make the whole world blow up.

Scientists have proved this could never happen. Only very special radioactive substances, such as U-235 or plutonium, have ever been made to explode.

If water, sand, salt, or pebbles are dumped on an ordinary fire, the flames go out. Similarly, if water, sand, salt, or rocks—the substances of which the earth is mainly composed—were put in an atomic bomb casing, they would also put out the atomic “fire” of the uranium. The earth is the wrong “fuel” for nuclear explosions.

Another fear was that an atomic bomb, accidentally dropped from a plane, would blow up anything it hit below. Such an accident happened, but there was no atomic blast. Only the TNT “trigger” went off, not the atomic bomb. Each atomic bomb has a complex internal mechanism that must be set



before it can explode. Atomic bombs being transported during peacetime are never set to explode. They are no more dangerous than a shipment of dynamite.

Nor can the atomic plants that are now being built ever blow up, even though tons of uranium are used in their reactors. If a reactor did go wild, it would only create great heat and melt itself. The molten uranium would become contaminated with graphite and metals in the reactor and go “dead.” Only highly purified uranium can fission.





Workers in atomic plant are protected from radioactive materials.

## Atomic Safeguards

Some real problems did arise with the coming of atomic power, but scientists are trying to solve them.

After the early atomic bomb tests, it was found that these explosions hurled radioactive particles into the air. This *fallout*, as it is called, is dangerous in concentrated form. For this reason all atomic tests are made in deserts or at sea, far from populated centers.

Getting rid of the atomic wastes that came out of atomic plants was another problem. Certain liquids and "ashes" from the reactors remain "hot," or radioactive, for long periods of time. This atomic garbage is buried under the ground or is sunk at sea after being placed in steel drums encased in concrete.

The workers at atomic plants are safeguarded from receiving dangerous nuclear radiations. Each worker wears a small strip of photographic film in his lapel. This film is checked regularly for "fogging." The film is fogged if any gamma rays touch it. If this should occur the worker can be referred immediately to a doctor for treatment.



Also, the workers must file past a Geiger counter at regular intervals. If the Geiger counter clicks rapidly, it means that a worker's clothing is contaminated by radioactive material. The clothing is then immediately replaced by clean and safe garments. Many of the atomic scientists wear special clothing into which leaden threads are woven. Lead, being dense, stops radiations.

Because of careful regulations, workers in atomic plants have a lower accident rate than in most other industries in the United States.



## Atomic Fusion

Having finally discovered how to bring about atomic fission, the nuclear scientists began to look for ways to bring about atomic fusion. Fission means splitting heavy atoms into lighter atoms. Fusion means just the opposite, building up light atoms into heavier atoms.

The clue to fusion was our own sun, which is a giant nuclear reactor. If it were made of coal, the sun would have burned itself out in a few million years. What has kept it producing light and heat for five billion years?

The answer to this question is the nuclear burning of hydrogen gas. Hydrogen gas composes over ninety percent of the sun. In the sun's hot interior, hydrogen atoms are fused into helium, which is another element. Four hydrogen atoms join together, under great heat, to form one helium atom. But the helium atom formed always weighs somewhat less than the four hydrogen atoms. The lost



weight is matter that turns into energy. This process follows Einstein's formula,  $E = mc^2$ . So much energy is released by this fusion that the sun will be able to stay hot for at least another ten billion years.

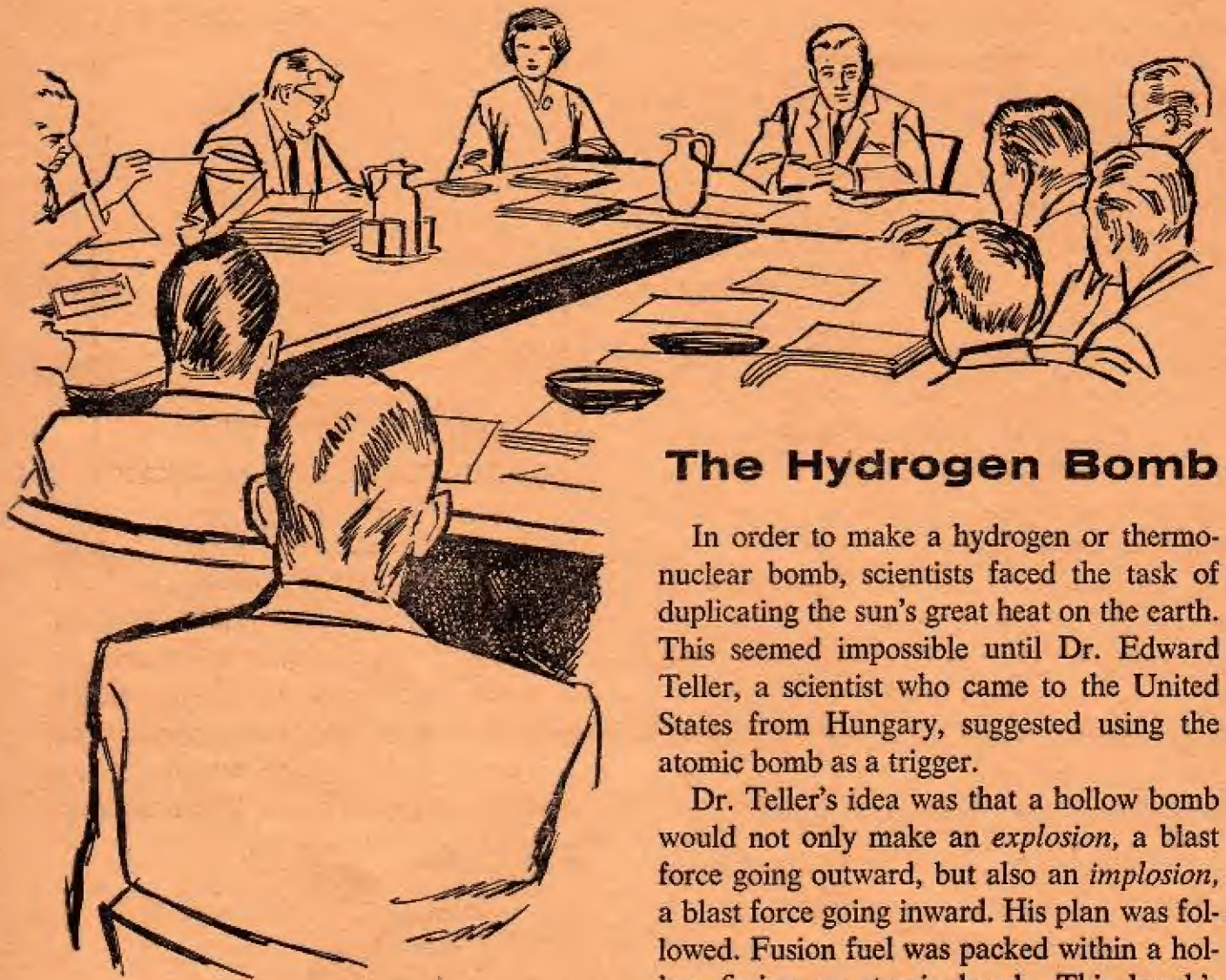
Atomic fusion is also called thermonuclear reaction. "Thermo" means heat. The sun's high internal temperature of 13 million degrees or more makes fusion take place.



The sun is a giant nuclear reactor.



Dr. Teller suggested using the atomic bomb as a trigger for the hydrogen bomb.



## The Hydrogen Bomb

In order to make a hydrogen or thermonuclear bomb, scientists faced the task of duplicating the sun's great heat on the earth. This seemed impossible until Dr. Edward Teller, a scientist who came to the United States from Hungary, suggested using the atomic bomb as a trigger.

Dr. Teller's idea was that a hollow bomb would not only make an *explosion*, a blast force going outward, but also an *implosion*, a blast force going inward. His plan was followed. Fusion fuel was packed within a hollow fission or atomic bomb. This bomb's powerful implosion, along with its explosion, heated the hydrogen core by millions of degrees. Then, only millionths of a second later, the hydrogen atoms fused into helium, just as they do in the sun.

This fusion released far greater energy than that released by the atomic bomb. Weight for weight, the atomic fusion of hydrogen is many times more powerful than the atomic fission of uranium. And, because hydrogen atoms are so light, a large number of them could be packed in a bomb. Atomic bombs are limited by the weight of the critical mass they carry.

PLACE THE STAMP HERE

FUSION RELEASES MORE ENERGY THAN FISSION



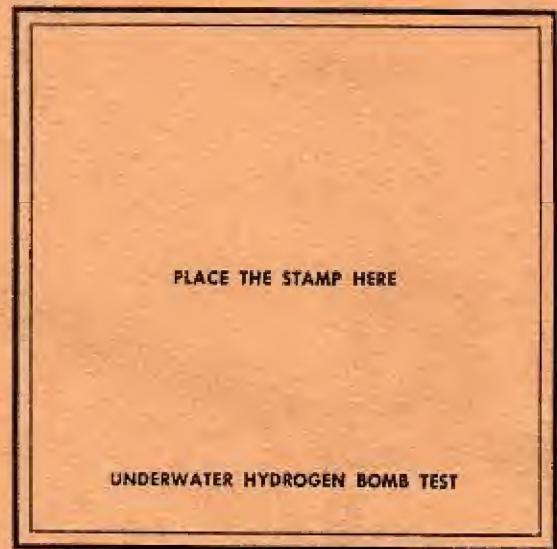
## Hydrogen Bomb Tests

The first hydrogen bomb was exploded in November, 1952, during a secret test near Eniwetok Island in the Pacific Ocean. Even the nuclear scientists underestimated the bomb's great power. They had to rate it by megatons instead of kilotons, each megaton being equal to a million tons of TNT.

The first hydrogen bomb of five megatons had the blasting power of five million tons of TNT, or ten times more power than the biggest atomic bomb of 500 kilotons.

As time passed, the fusion bombs became even more powerful. On March 1, 1954, an island called Bikini Atoll was completely destroyed by a 15-megaton bomb.

The earliest hydrogen bombs required complicated electronic devices, timing mechanisms, and other equipment. Since they were too heavy for a bomber plane to carry, they were exploded on the ground by remote-control. It was not until May, 1956, that a hydrogen bomb had been made light enough to be carried by plane.



Now, hydrogen bombs of power up to 50 megatons have been built. Though the details are secret, it is said that such bombs are packed with a large amount of uranium as well as the fusion fuels. Fission and fusion happen at the same time in these bombs. This fission-fusion bomb is neither an atomic bomb nor a hydrogen bomb. It is more properly called the nuclear bomb.



Hydrogen bomb test



# Heavy Water

The hydrogen bomb does not use ordinary hydrogen gas for atomic fusion into helium. Instead, it uses a special kind of hydrogen that occurs in a rare form of water called "heavy water."

The molecules of heavy water contain hydrogen and oxygen—like ordinary water—but the hydrogen atoms are of a special heavy type, known as deuterium.

In deuterium atoms, the nucleus contains both a proton and a neutron. In an ordinary hydrogen atom there is only a single proton. This makes the deuterium atom twice as heavy or double the atomic weight of the usual hydrogen atom.

Atomic plants also make tritium-hydrogen, in which the atoms are triple the weight of regular hydrogen atoms. In tritium, each nucleus combines two extra neutrons with one proton.

Tritium is very radioactive and unstable. It is ideal for thermonuclear reactions since it will fuse readily with deuterium. Dissolved lithium-6, a radioactive form of the metal lithium, is also used along with the heavy water in hydrogen bombs.

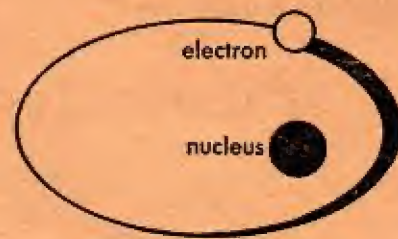
Deuterium, tritium, and lithium-6 create

the vast explosive power of the hydrogen bomb. A uranium-fission atomic bomb is used as the trigger to furnish enough heat to start off the fusion chain reaction.

In millionths of a second, with an atomic bomb acting as a fuse, the deuterium-tritium-lithium core of the hydrogen bomb achieves atomic fusion. The two explosions are almost simultaneous.

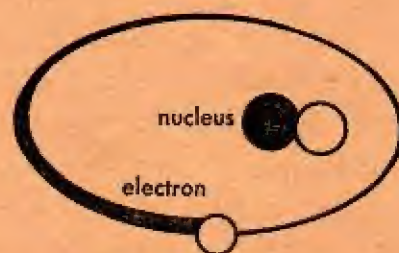
Three Types of Hydrogen Atoms

1. light hydrogen



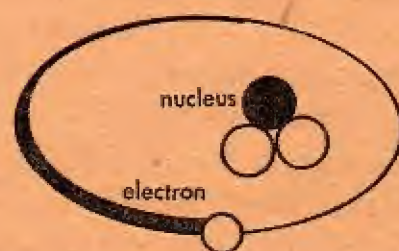
nucleus contains 1 proton

2. heavy hydrogen



nucleus contains 1 proton and 1 neutron

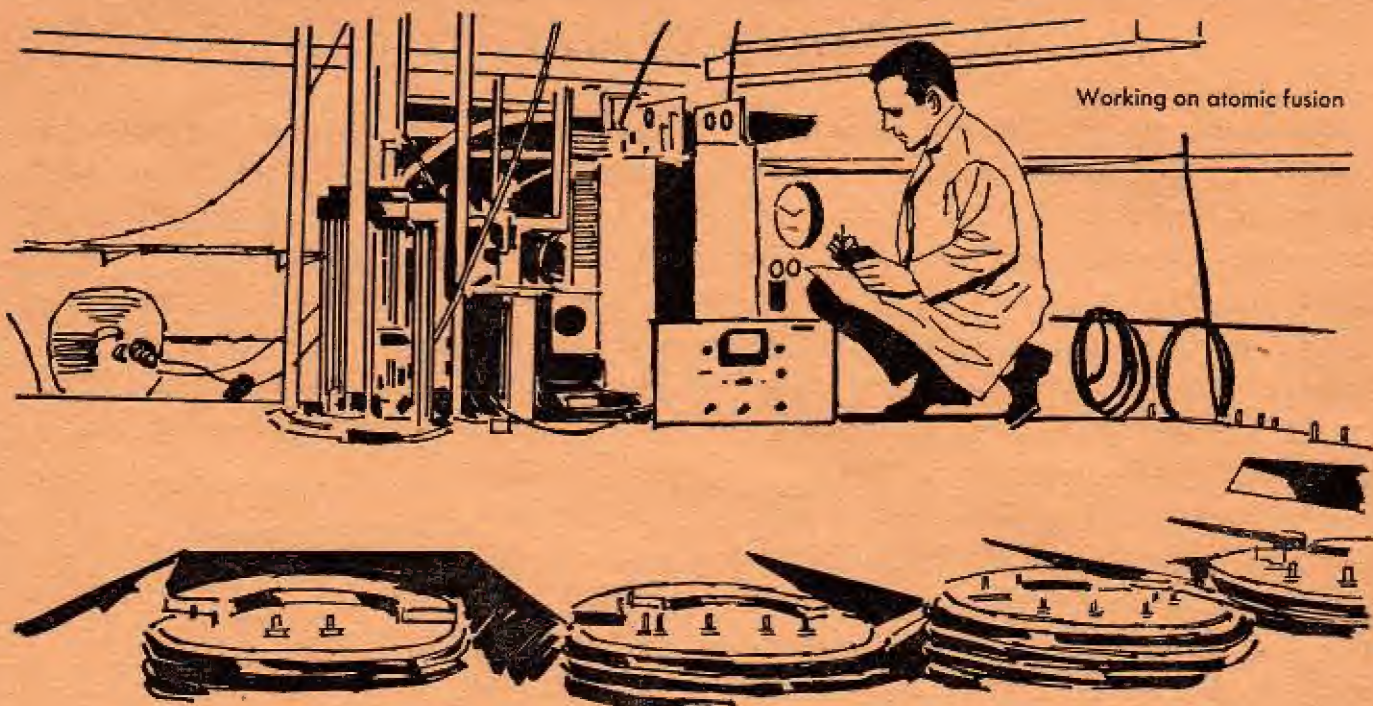
3. triple-weight hydrogen



nucleus contains 1 proton and 2 neutrons







## Power From Atomic Fusion

Someday we will use atomic fusion for power. However, this is not nearly as easy as using atomic fission. Thermonuclear fusion reaction starts only at heat of more than ten million degrees, the same degree of heat found in the sun's molten center.

Any metal, glass, plastic, or ceramic we know would instantly melt and vaporize at this degree of heat. How could any container or reactor hold up in that extreme temperature? It seemed impossible until scientists invented a magnetic bottle.

A magnetic bottle is a glass tube into which ionized, or electrified, hydrogen gas is pumped. Surrounding the tube is a powerful magnetic field that makes the ions, or charged atoms, shrink away from the glass walls and pinch close together in the center. This is called the "magnetic pinch effect."

Very high-voltage electricity is then shot into the tube, raising the temperature of the gas ions to millions of degrees. These ions do not melt the glass tube because they are not touching the glass walls. The very high

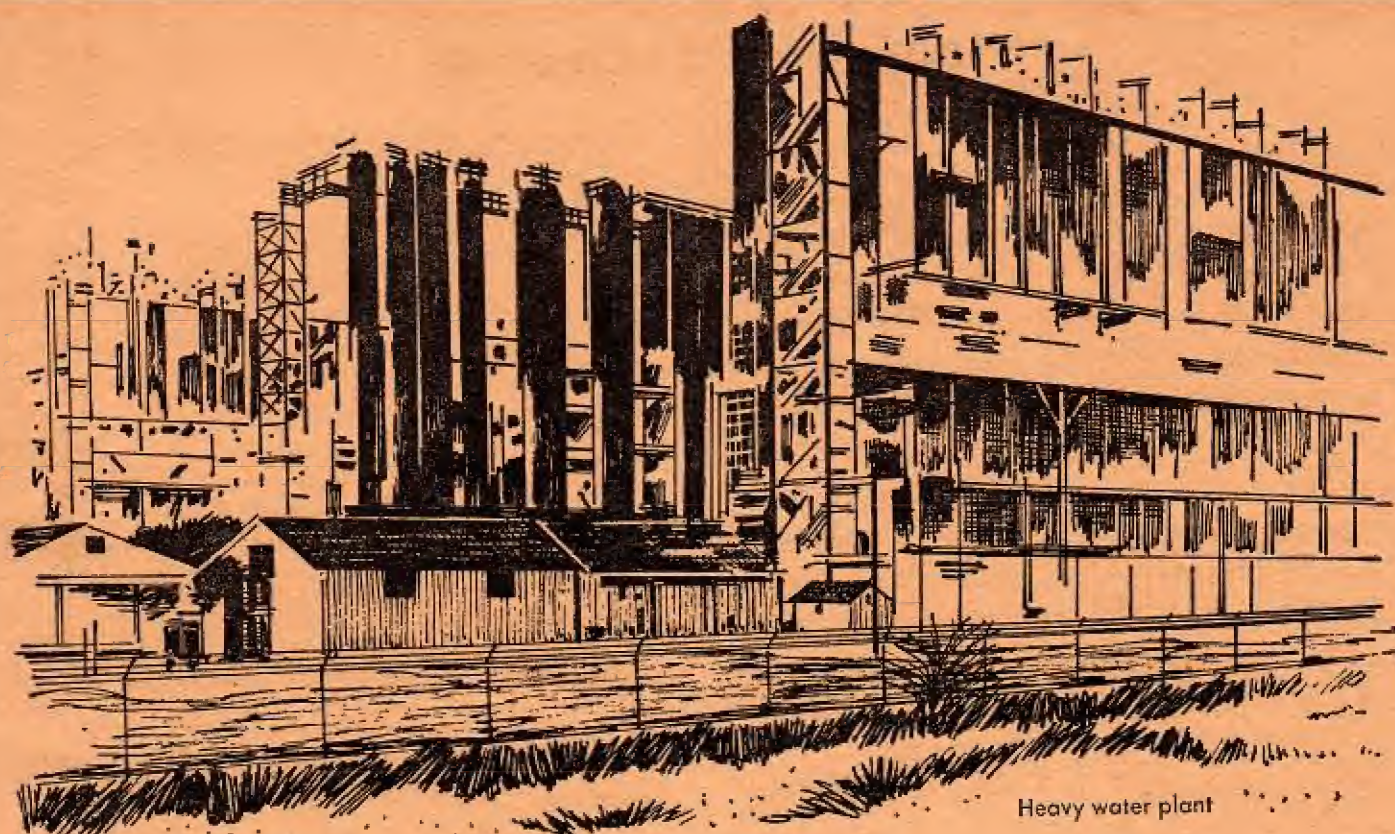
temperature, plus the magnetic pinch pressure, are supposed to start atomic fusion.

However, this sudden flash heat can only be kept up a few thousandths of a second at a time. It is not enough to start a chain reaction that will produce steady power.

British, American, and Russian scientists are all experimenting with atomic fusion, but it may take years of research to release this power for practical use.







Heavy water plant

## The Cheapest Fuel

When fusion reactors are invented, their fuel will be the deuterium in heavy water. Heavy water is now produced for \$28.00 a pound. Pure uranium-235, needed for fission reactors, costs \$12,000.00 a pound. The fuel for fusion reactors will be much cheaper than that for fission reactors.

Also, deuterium is much more plentiful than uranium. In sea water, one out of each 6,000 molecules is composed of heavy water which contains deuterium. Since the oceans cover almost three fourths of the earth's surface, the total amount of deuterium in all the world's sea water is many trillions of tons.

Countries bordering on the sea could build plants to distill heavy water from sea water. They could then sell this heavy water to inland nations. Thus, no matter how poor a nation was in its supplies of coal, oil, or uranium, it could use deuterium for fusion reactors to obtain electrical power.

Each pound of heavy water now costing \$28.00 will produce electrical power equal to \$5,000.00 worth of coal. It will be cheaper when mass-produced in the future. The deuterium from two gallons of heavy water would produce enough electricity to light your home for 9,000 years.





## Nuclear Treasure

The world will be using atomic energy from fissioning uranium a long time before it can use energy obtained from atomic fusion.

After the war, large quantities of uranium were needed to develop peacetime reactors. Prospectors all over the world began hunting for uranium.

Uranium ores were found in many sections of the earth but the richest deposits were in Australia, Portugal, the Belgian Congo, Canada, Russia, and North America. In the United States, uranium is plentiful only in the West. Colorado has the major supply of these ores.

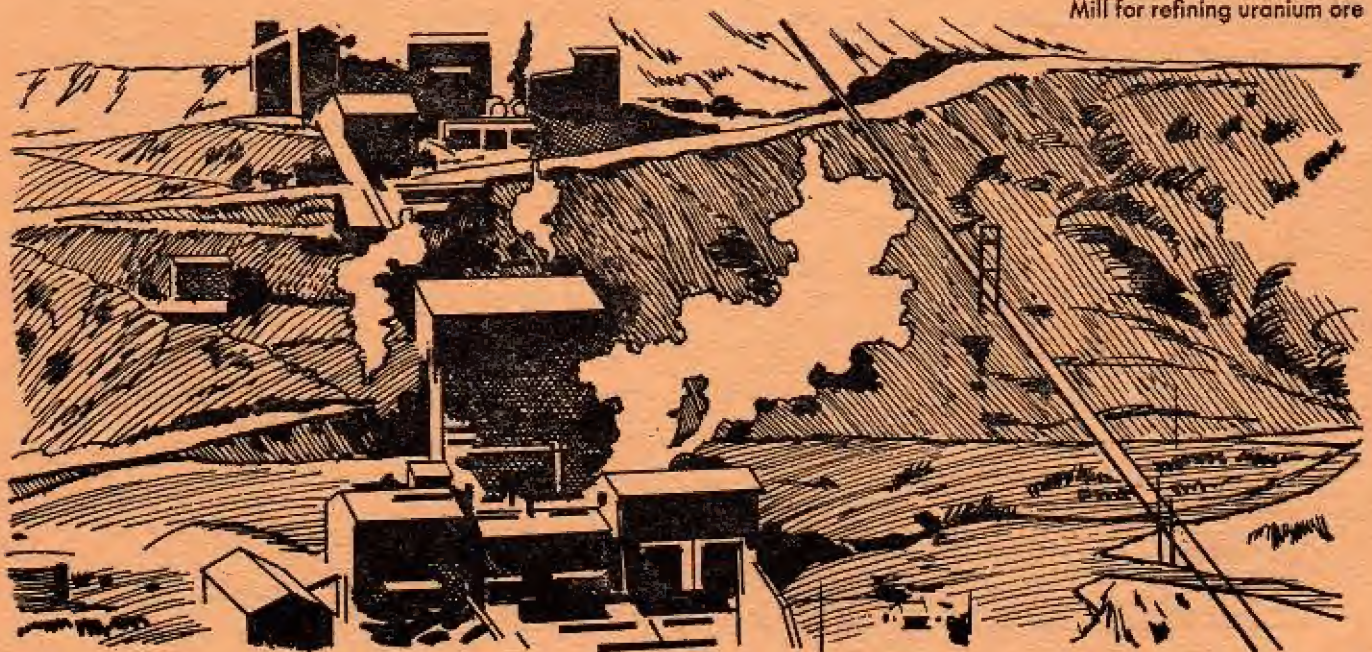
The uranium prospector has to use a special device called the Geiger counter. This is an electronic instrument that is sensitive to the radiations—the alpha, beta, and gamma rays—given off by any radioactive mineral.

When the Geiger counter makes loud clicks, the prospector knows that uranium ore is nearby, either in the rocky ground or in a cliff. The number of clicks per second tells the prospector how rich the ore is, and how much of it lies at that spot.



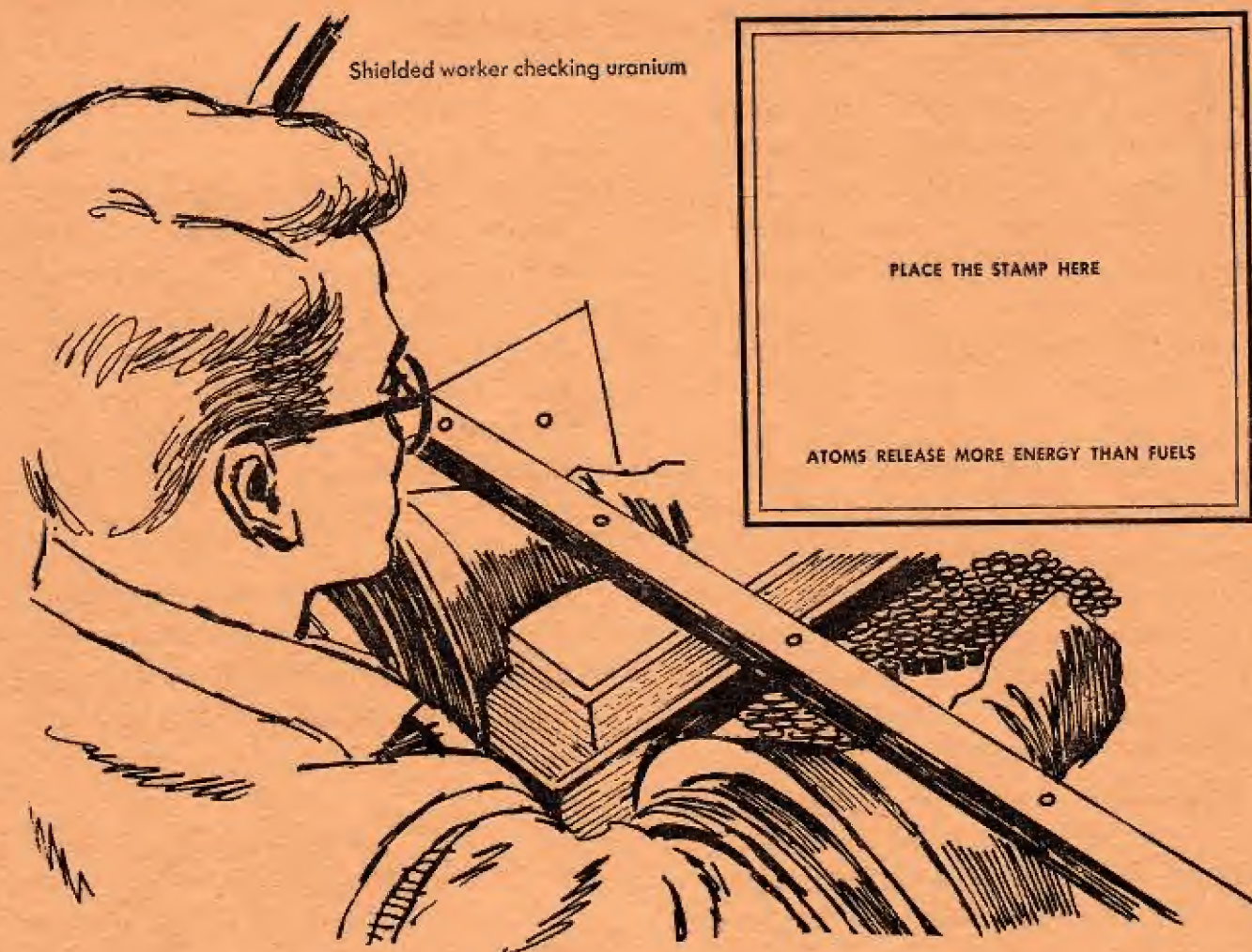
After 1948, many uranium strikes were made by prospectors. One man who found uranium sold his claim for \$9,000,000. Others have also struck it rich, but many failed, for good uranium ores are almost as hard to find as gold is.

By federal law, the United States government is entitled to buy all uranium ores mined in this country. These ores are refined for use by the AEC. Today, over a billion dollars' worth of uranium is mined each year.



Mill for refining uranium ore





Shielded worker checking uranium

PLACE THE STAMP HERE

ATOMS RELEASE MORE ENERGY THAN FUELS

## Matter is Energy

The United States government has spent billions of dollars buying uranium for the AEC. It is well worth it, however, when we realize the huge amount of power locked up in the atom.

One pound of uranium metal makes a cube one inch square, which is about the size of an ice cube. If all of its atoms were split, that one pound of uranium could produce 11 million kilowatt hours of electricity worth \$500,000.00. Yet one pound of uranium (in which U-238 and U-235 are mixed) costs only about \$15.00.

In present reactors, only part of the atoms are fissioned and the rest are wasted. Even so, one pound of uranium can give us energy

equal to five tons of coal, or 1,000 gallons of gasoline. What makes this great difference?

The burning of coal is a chemical process, in which the atoms of the coal combine with atoms of oxygen to produce heat. The combustion turns the coal and carbon into carbon dioxide gas. The atoms themselves are not changed because their nuclei are untouched.

On the other hand, fission changes uranium atoms by splitting their nuclei into smaller, different atomic nuclei. This causes a loss of mass which turns into energy.

From the chemical burning of coal, or any fuel, we get only low-grade heat-energy. It is a million times less than the nuclear energy obtained from splitting the nuclei of atoms.



## Inside the Reactor

The reactors built by the AEC were great improvements over Fermi's first atomic pile of 1942. Many different reactors were devised, but they have several basic features in common.

All reactors have a core containing the fission fuel. The fission fuel may be U-238 plus U-235, plutonium, thorium, or combinations of these elements.

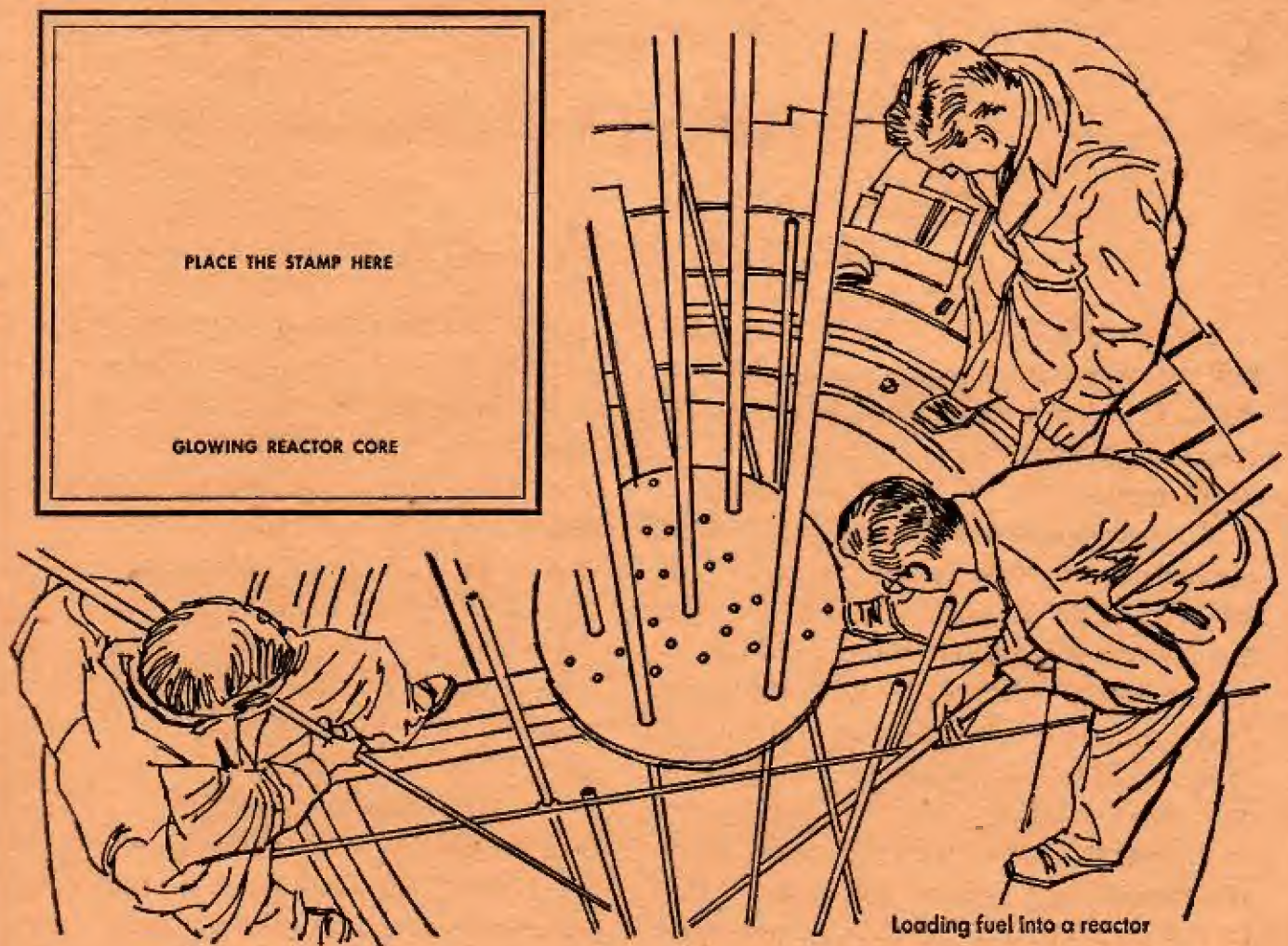
Within this core is a moderator that slows down the neutrons. Slow neutrons are more effective in penetrating a nucleus of an atom, and thus starting a chain reaction.

The moderator must be a substance that lets neutrons pass through it, and come out at a slower speed. Graphite and heavy water are good moderators, but a metal called

zirconium is the best moderator. This metal is lighter than steel, resists corrosion, and will not melt under heat of 3,452 degrees.

When the chain reaction starts and the reactor goes critical, great heat is produced. This heat would soon melt the core unless the core is cooled. The cooling is done with pipes through which a coolant flows, absorbing and removing the heat. Plain water is often used for the coolant. Metals with low melting points like sodium and potassium are also used.

In a reactor everything is done on a large scale. The core may contain more than 100 tons of fission fuel, which calls for many tons of moderators, and thousands of gallons of circulating coolant.



Loading fuel into a reactor



## Taming the Atom

The core, moderator, and coolant system are only parts of the reactor. Surrounding the reactor is the shield which stops the deadly radiations. The shield may be a very wide jacket of water, or heavy steel armor reinforced with lead, or ten-feet-thick concrete. It takes such materials to stop the powerful rays hurled out from the reactor's core.

Finally, extending from the core out through the shield, are the control rods with which the scientists regulate the reactor.

The control rods are made of cadmium, steel, boron, or a metal called hafnium. The rods can absorb and stop neutrons. Thus, when they are thrust deeper into the core, they take enough neutrons out of action to slow down or to stop the chain reaction. When they are pulled out, the core fissions more and more rapidly.

The control rods are necessary to keep the reactor running steadily and to prevent its fissioning too rapidly. However, should the fission occur too rapidly, the reactor would

not blow up like an atomic bomb. The runaway reaction would create intense heat and most likely would melt the uranium, graphite, zirconium, and other core materials into a "non-critical" mass. But, it would ruin the reactor. The AEC has seen that safeguards are taken so that an atomic plant can never explode.

Including all the parts and the huge shield, the typical reactor plant is very large, often fifty or a hundred feet wide.

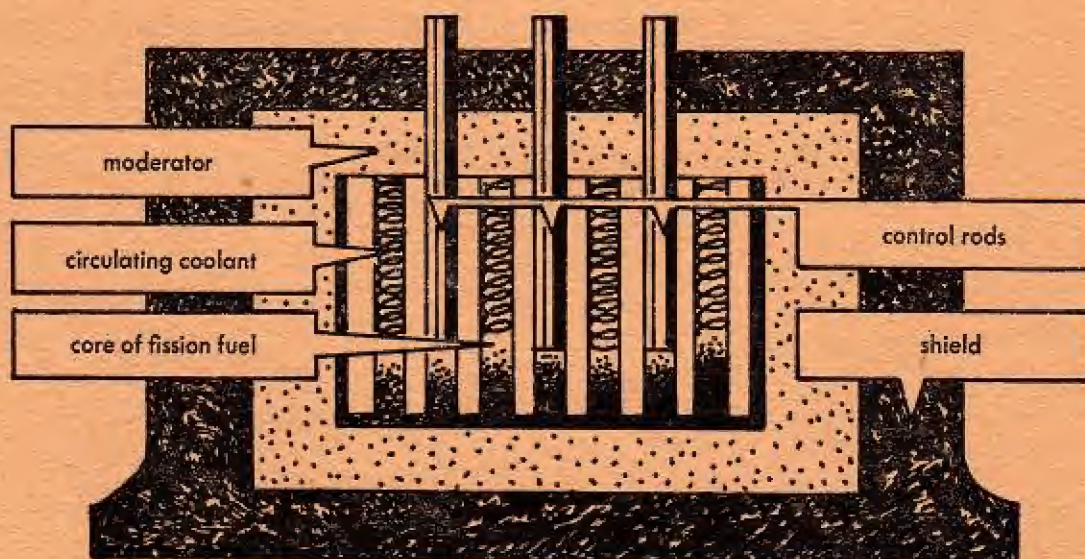
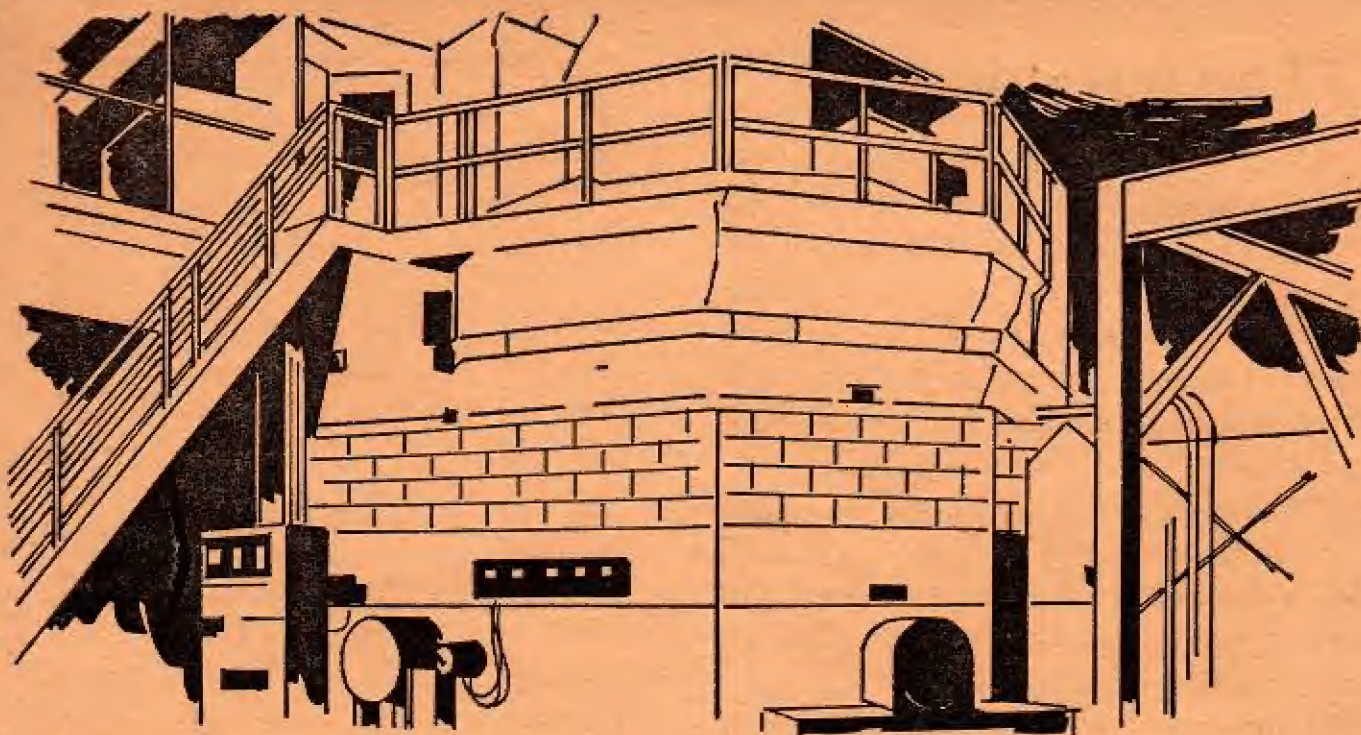


Diagram of a Reactor





A breeder reactor

## The Fuel that Increases

When coal is burned, only ashes that cannot be used again are left. But the "ashes" from a certain type of atomic reactor can actually contain more fission fuel than was originally put in the reactor. This type of reactor is called the breeder reactor.

In all reactors, only a small part of the uranium is used up, the U-235 breaking down into light atoms, the U-238 building up into plutonium.

By using fast neutrons for bombardment, the breeder reactor not only breaks down as many atoms as is necessary to produce atomic energy, but also increases the percentage of plutonium formed. This fast-neutron process, as it is called, thus increases the overall efficiency of the reactor.

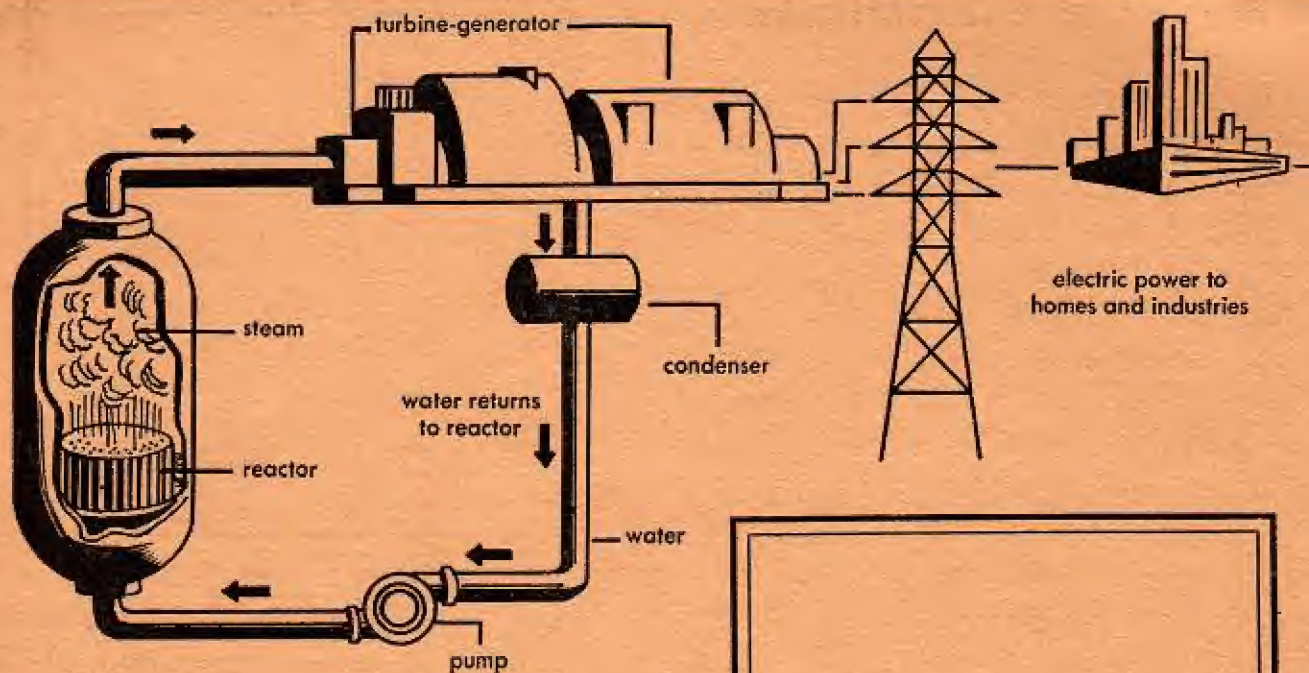
After it has been operating for a while, the breeder's core can be opened and the freshly made plutonium extracted in large amounts. Month after month, this reactor creates new radioactive fuel in its "ashes" so that its fuel cost is actually zero. During all this time, the

reactor has been producing atomic power, too.

In the future, when atomic energy is used throughout the world, countries that have small supplies of uranium ore can use the breeder reactor to their advantage. They will have to import the original uranium core, but, when that is gone, they will have a supply of plutonium on hand to furnish more power.







## Atomic Power Plants

The research laboratories of the AEC have developed over 30 types of reactor systems for producing industrial power in the future. These reactors have many variations of fissioning cores, moderators, coolants, control rods, and shielding. Yet, they all do the same job.

It is only the heat from the atomic reactor that is used for power. And this heat simply runs a conventional steam engine, or its equivalent.

Some of the reactor systems heat ordinary water to produce ordinary steam. This is done by running water pipes through the hot core. But this heated water becomes radioactive and therefore dangerous to the workmen in the plant. It is used only to heat other water in a boiler. This type of reactor system is called a heat exchanger. The secondary water in the boiler then turns to uncontaminated steam.

Instead of water, some reactor systems use a metal, like sodium, that melts easily.

PLACE THE STAMP HERE

INSTALLING A REACTOR

It is run through the pipes in the core, and then used to heat up the boiler. Molten metals can get hotter than water and thus produce higher steam pressure.

There are many other ways of using atomic heat, but once the steam is produced, the end result is the same. The steam is used to run electric turbine generators, just as the steam from coal is now used.

The big difference is that, at the present time, one pound of uranium produces as much steam as 10,000 pounds of coal. As yet, reactors use only a small fraction of the power in fission fuels, while the rest of the fuel becomes atomic waste. If all the atomic energy in a pound of uranium were released, it would equal 2,600,000 pounds of coal.



## Atomic Electricity

On December 2, 1957, at Shippingport, Pennsylvania, the first commercial reactor in America went critical. It then began supplying 60,000 kilowatts of electricity to the nearby city of Pittsburgh.

Sometime in 1960, several other atomic power plants will be finished and will start operating. They will produce electricity to light homes, to run factories, and to furnish power for many machines.

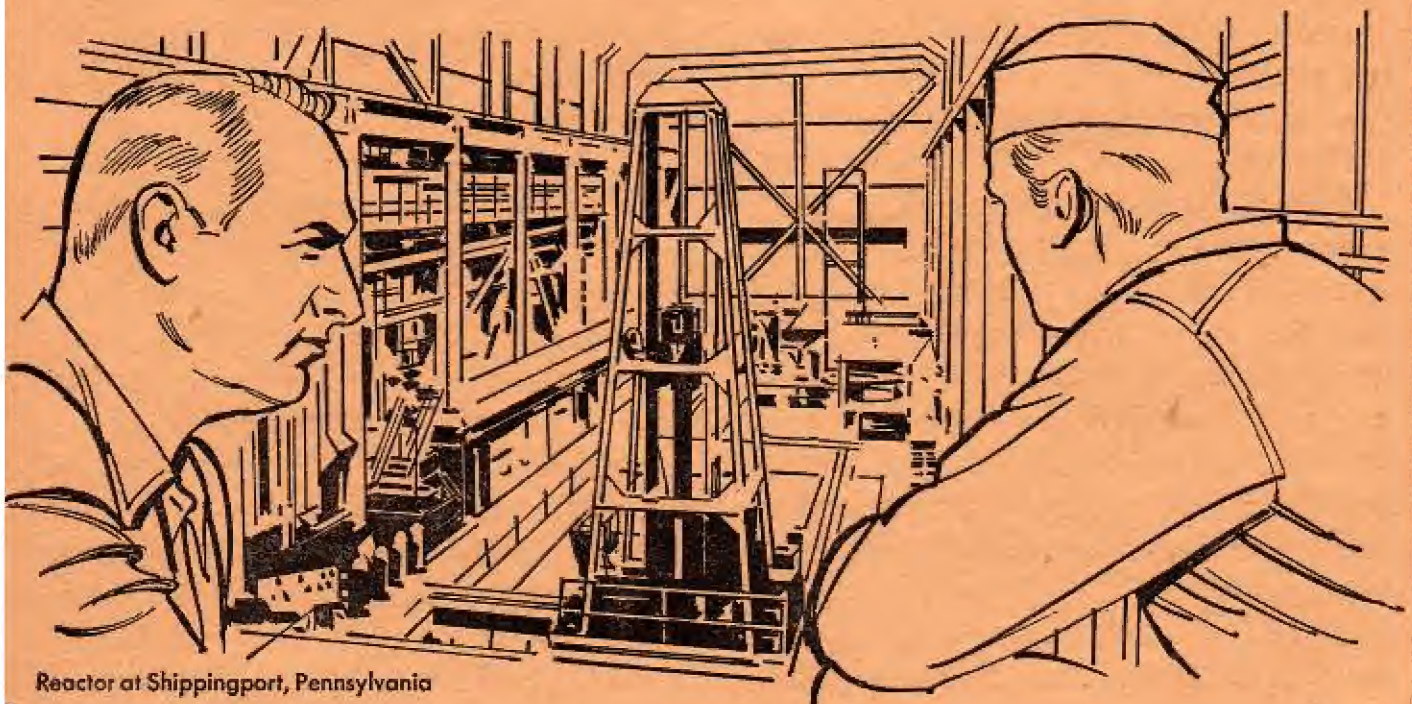
The United States government, by furnishing the necessary fission fuel and atomic data through the AEC, is assisting private utility companies in this new venture. The utility companies are building their own plants and reactors.

The sites picked are those where it is costly to ship coal or oil, or where expanding industries need more electricity than has previously been supplied. Coal and oil reserves, though plentiful in the United States now, will dwindle in future years. As time goes on, more and more atomic power plants will be needed to supply electricity.



Each of the atomic power plants now being built will produce anywhere from 60,000 to 250,000 kilowatts. This is enough electricity for cities of from 75,000 to 300,000 people.

At first, the electricity will not be produced as cheaply as it is by coal because of the high cost of building the huge plant and its expensive reactor. But in the end, the cost of the uranium fuel will be far less than coal, and, as a result, cheaper electricity will be produced.



Reactor at Shippingport, Pennsylvania



## The Atom Abroad

England holds the distinction of operating the first commercial reactor in the Western World. The Calder Hall plant, in northern England, began producing 40,000 kilowatts in 1956. Since then the British have opened other atomic plants to produce electricity, and are building more as fast as they can.

The British have good reasons for rushing into the commercial use of atomic energy. Unlike those of the United States, their coal supplies are running out rapidly. And, they must import, at a high cost, all the oil they use. Atomic power promises to make up for their lack of fuels and to give them cheaper electricity.

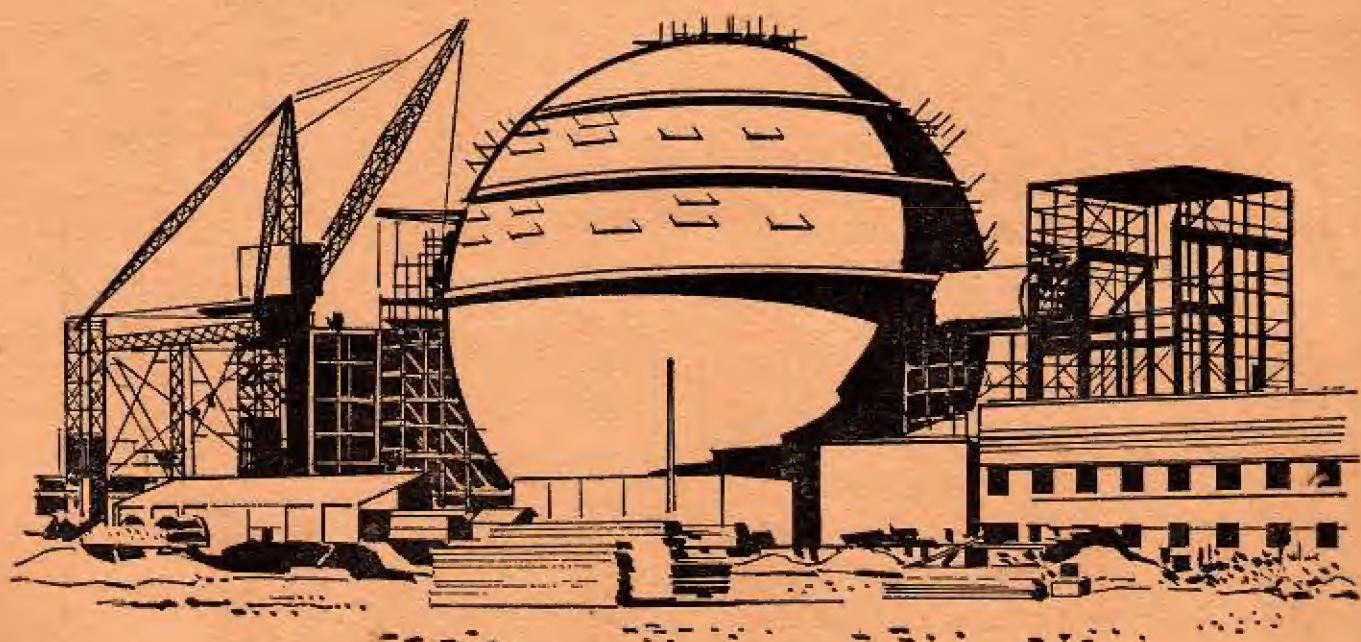
Because they started construction several years ago, the British used the earlier types of reactors. These reactors used a large amount of fission fuel to heat up steam. But even so, such reactors helped make up for the British coal shortage.

The English plan to keep building atomic



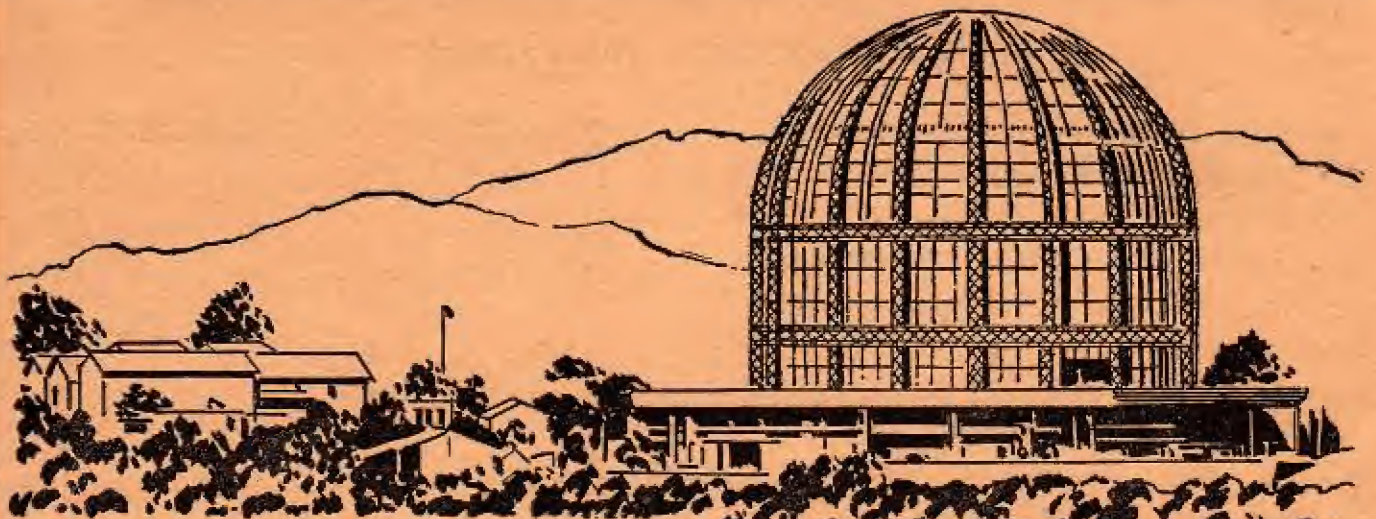
plants so that by 1975 almost one half of all their country's electricity will come from uranium. Then, even though British mines may be forced to shut down because of the lack of coal, the country will be safe from a shortage of fuel to run industries.

The atom has given the British a new and brighter future.



A breeder reactor in northern Scotland





## The Atom's Promise

Other nations, besides Britain, have begun to use commercial atomic power. Norway, Sweden, France, and Russia already produce some of their electricity in atomic plants. These countries, like England, face a shortage of coal and oil.

To nations all over the world, that have never had enough fuel to run their industrial machines, the atom promises a better future. Italy, India, and Japan are poor in coal or oil, as are many of the nations of South America and Africa. Such countries have had little opportunity before to make enough electricity to run big industries.

The solution to their economic problems may be atomic power plants. Such countries as Bolivia, Burma, and Ghana will then be able to use their own natural resources, like ores and raw chemicals, instead of having to export these resources to manufacturing nations. It is hoped that new wealth and prosperity will spread around the world with the fissioning atom.

Many countries, lacking coal and oil, are unable to develop industries. The Atomic Age will give these nations an opportunity to raise their living standards to those of the present industrial nations.



Atomic plant at Thrombay, India





## Atoms for Peace

A great international program for atomic power is now under way. It was started by the United States in 1953, when President Eisenhower proposed an atom pool to the United Nations. This proposal was approved in 1955, as the *Atoms for Peace* program.

Under this program, the nations furthest ahead in atomic research—the United States, Russia, and Britain—agreed to help 82 other nations to build atomic plants. The United States pledged 22 tons of U-235 and 129 tons of heavy water to be shipped to other countries immediately with more to follow later. Shiploads of basic materials for atomic plant construction, as well as teams of atomic experts, were sent abroad from the United States.

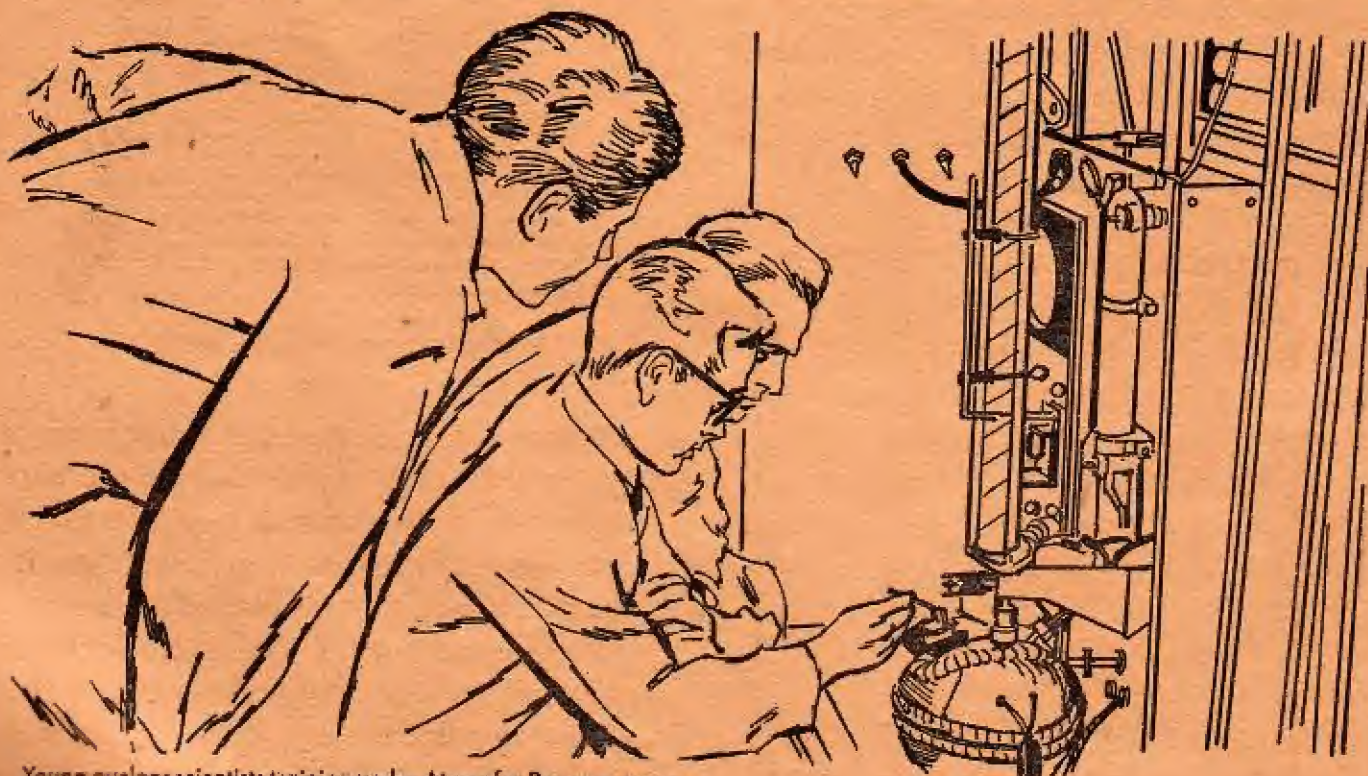
Many European and South American nations, aided by this program, are now building atomic plants. But progress is often slow. In some countries there are few scientists or technicians to run the plants, even when they are built. For this reason the Atoms for Peace



project is, in many cases, first providing education and training.

Non-industrialized nations must also be helped to plan for ways to use the power produced by atomic plants. Electricity produced by atomic energy is of little benefit if a country has no factories nor electric power available to most homes.

It may take years before this program can benefit all the nations of the world.



Young nuclear scientists training under Atoms for Peace program



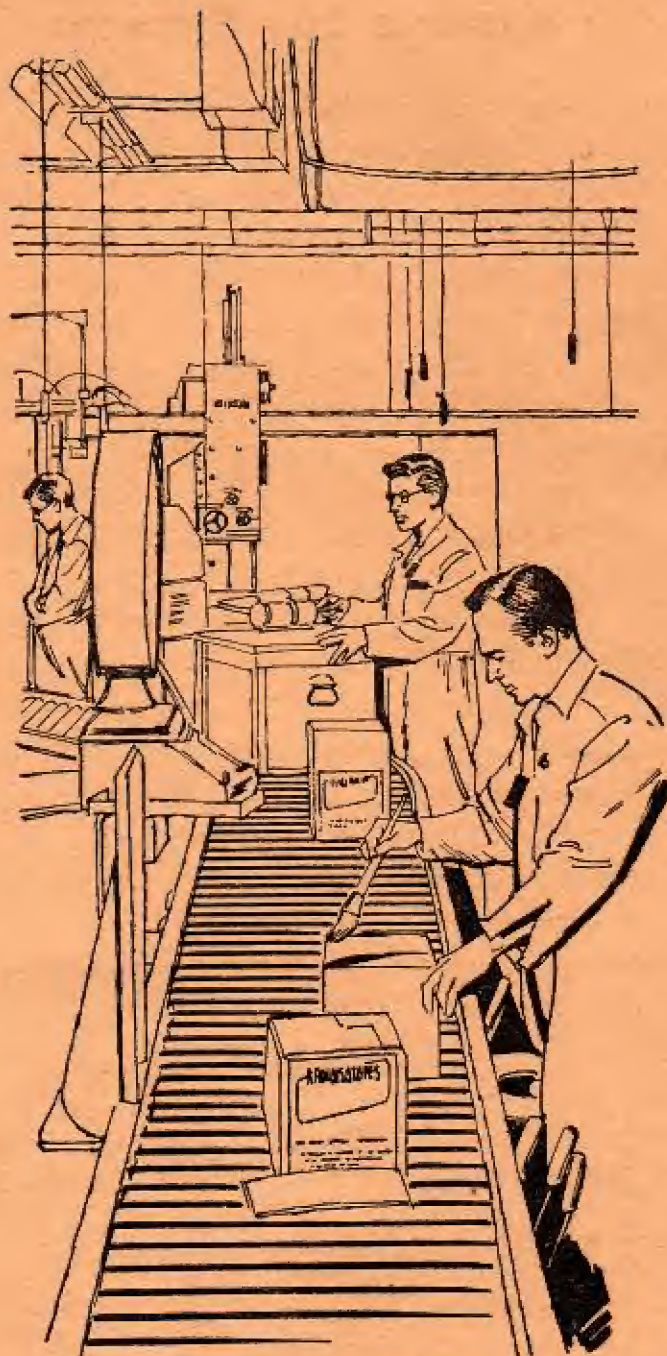
## Radioisotopes

Out of atomic reactors, cyclotrons, and other atom-smashing machines have come hundreds of radioisotopes of the elements.

Atoms of the same element may have a different number of neutrons in their nuclei. An isotope is an atom that has the same number of outer electrons, but a different number of neutrons in its nucleus. Thus, isotopes are different in *atomic weight*, but not in *atomic number*, since this is based on its circling electrons.

Many elements found in nature consist of natural isotopes. Tin, for instance, has ten isotopes all mixed together. These are stable isotopes that have always existed on the earth. The new man-made radioisotopes are radioactive and unstable.

Cobalt-60 is one of the new radioisotopes. This is created by placing ordinary cobalt, which is a mixture of isotopes from Co-55 to Co-59, in an atomic reactor. The neutrons in the reactor are absorbed into the cobalt nucleus, increasing its atomic weight to Co-60. These cobalt atoms are unstable and break down, giving off intense radiations in the process. The rays from Co-60 are more powerful than those of radium.

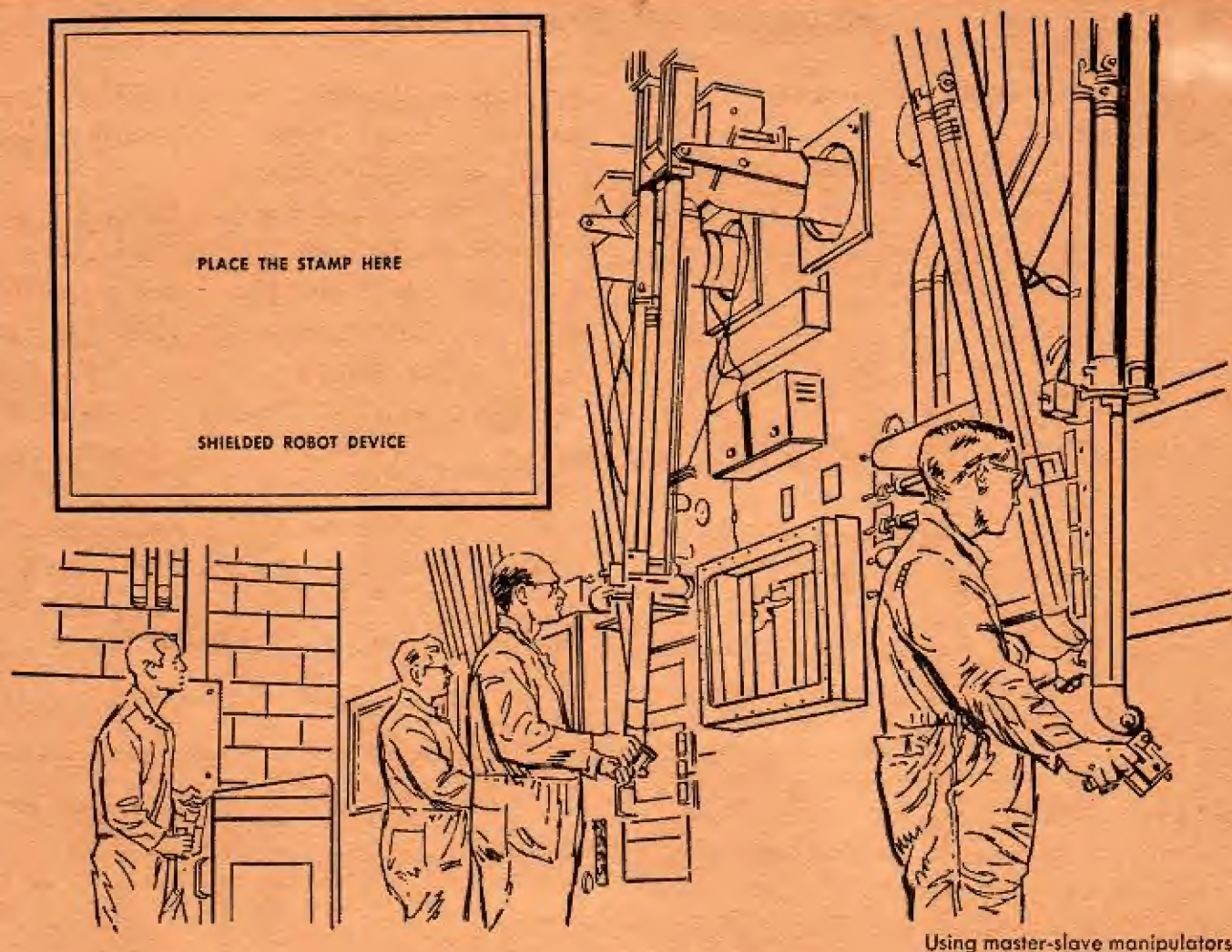


Preparing radioisotopes for shipment

Many radioisotopes can be made out of the same element. All are radioactive to some degree. In recent years, a large number of radioisotopes have been used in medicine, industry, chemistry, and many other fields.

Atomic reactors are now used mainly for producing radioisotopes, which are then sent out for commercial use. Today more than 800 different radioisotopes are available.





Using master-slave manipulators

## Atom Robots

After isotopes have been made radioactive in the reactor's core, men cannot take them out. The radiations would be far too dangerous. Robot devices do this job.

Many robot devices, called slavo-mechanisms and servo-machines, have been developed to handle radioactive material. A mirror system allows the scientist to look into the glowing core of the reactor. Using a set of levers or push buttons, he then makes a robot arm reach down into the core. Steel claws pick the container of radioisotopes out of the core, and place it on a chute to a laboratory.

In the laboratory, a scientist stands safely behind a thick shield and looks through a small glass window. He makes his slave

mechanism test the product, and then pack it in a leaden box for shipment.

Some robot devices are on wheels, allowing the scientist to move about the laboratory in them. In some cases, the scientists who work with radioisotopes wear hooded suits, which protect them from head to foot.

But the robots must still be used to actually handle radioactive matter. Many of the slavo-mechanisms have huge steel claws, but they handle fragile glass or plastic containers with a delicate touch. They faithfully make any movement their human masters want.

Without these mechanical slaves, scientists would find it impossible to handle radioisotopes.



## Atoms in Medicine

Today, radioisotopes are proving to be the "wonder atoms" of medicine.

It was known for many years that rays from radium could kill cancer cells. However, the total amount of radium in the whole world is only five pounds.

Then radiocobalt, which could be produced in large quantities, was found to be as effective in treating cancer as radium. One ounce of Co-60, which costs about \$1,000.00, is equal in power to \$50,000,000 worth of radium.

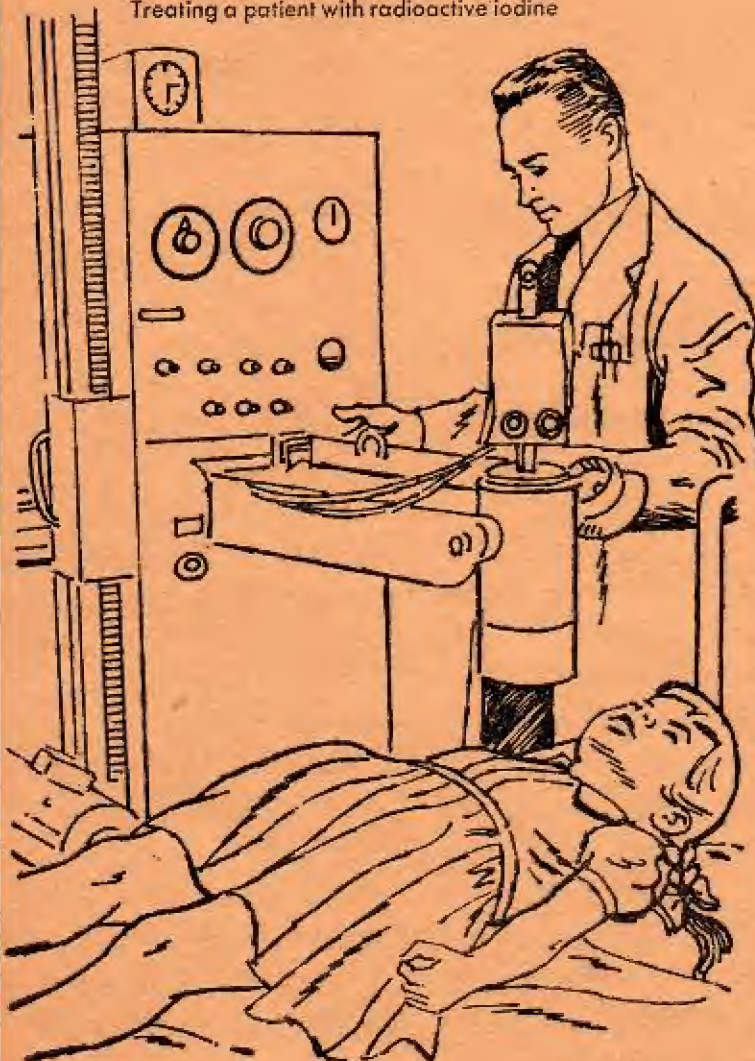
Another new weapon against disease is radioactive iodine. It is used in the treatment of hyperthyroidism, a disease in which

the thyroid gland becomes overactive. Surgeons have found it difficult to remove a part of the tiny thyroid gland.

Scientists knew that iodine in foods concentrated in the thyroid gland. So, the patient with hyperthyroidism is fed a salt of iodine-131. This radioisotope gathers in the thyroid gland where its powerful radiations can destroy part of the gland. The radioactivity of the iodine stops in a short time, and does not harm the patient.

These are only two of the many ways in which radioisotopes are being used in medicine. The AEC is making thousands of shipments of radioisotopes to hospitals yearly.

Treating a patient with radioactive iodine



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PATIENT GETTING RADIOCOBALT TREATMENT



## Nuclear Detectives

Common salt is a chemical compound called sodium chloride. Its radioisotope form does not give out severe radiations and radioactive salt can be eaten safely. When it is given to a man, the radioactive salt is carried through his body by his blood stream. Then, if a Geiger counter is placed near any part of his body, its clicking will tell where the radioactive salt has circulated.

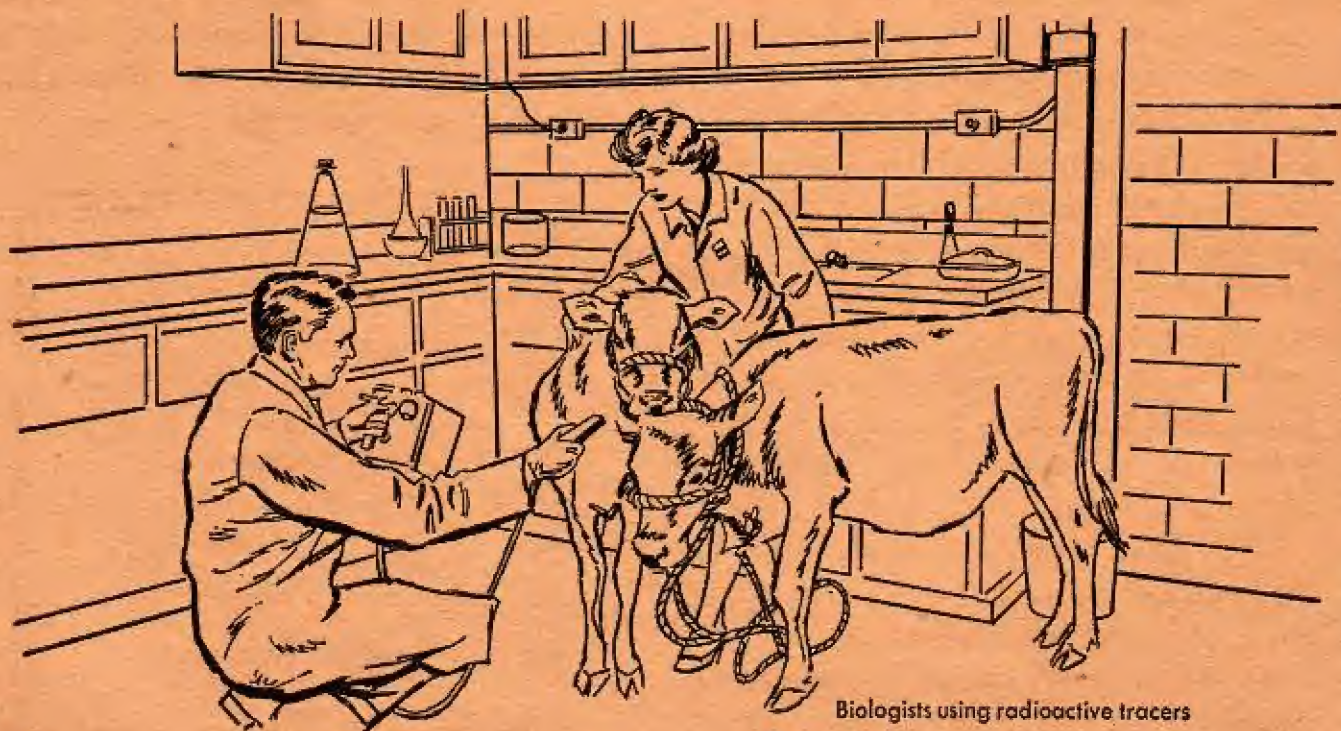
Biologists have recently found out, by this method, that salt travels all through the human body in fifteen minutes. This is one example of how radioisotopes are used as tracers.

Radioactive tracers are used in many ways in industry. They can show where wear occurs in pistons and bearings in machines. The flow of oil through pipe lines can also be checked by tracers.

Even a few radioactive atoms among millions of normal atoms can be detected by the sensitive Geiger counter. Thus radioactive tracers can be used to reveal the flow of sap

in trees, to follow the flight of an insect in the air, to trace invisible gases, or to mark the path of water soaking into soil. The list is endless.

Today tracers are used by over 10,000 industrial firms and scientific research teams. These atomic detectives are helping us solve problems about unseen life processes as well as industrial processes.



Biologists using radioactive tracers





Hybrid corn produced by radiation may improve corn crops.

## Atomic Agriculture

At AEC research farms, the radiations of radioisotopes are being used in an effort to improve crops. For instance, a pole holding radiocobalt is placed within a field of growing corn. The radiations, which spread through the field, have the amazing power to change the rate of growth of the plants.

Some of the corn kernels are also changed so that a mutation, or hybrid, is produced. Many hybrids, most of which are inferior, result from the radiations. However, one or two hybrids may produce better corn—for example, a plant that grows bigger ears, or needs less water, or one that can resist corn-plant diseases. These new qualities can then be bred into normal corn, which will improve the farmer's crop.

Many other grains and vegetables are being improved by radiation, as are poultry, cattle, and other farm animals.

Radioisotopes are also being used to make insecticides far more powerful than chemical

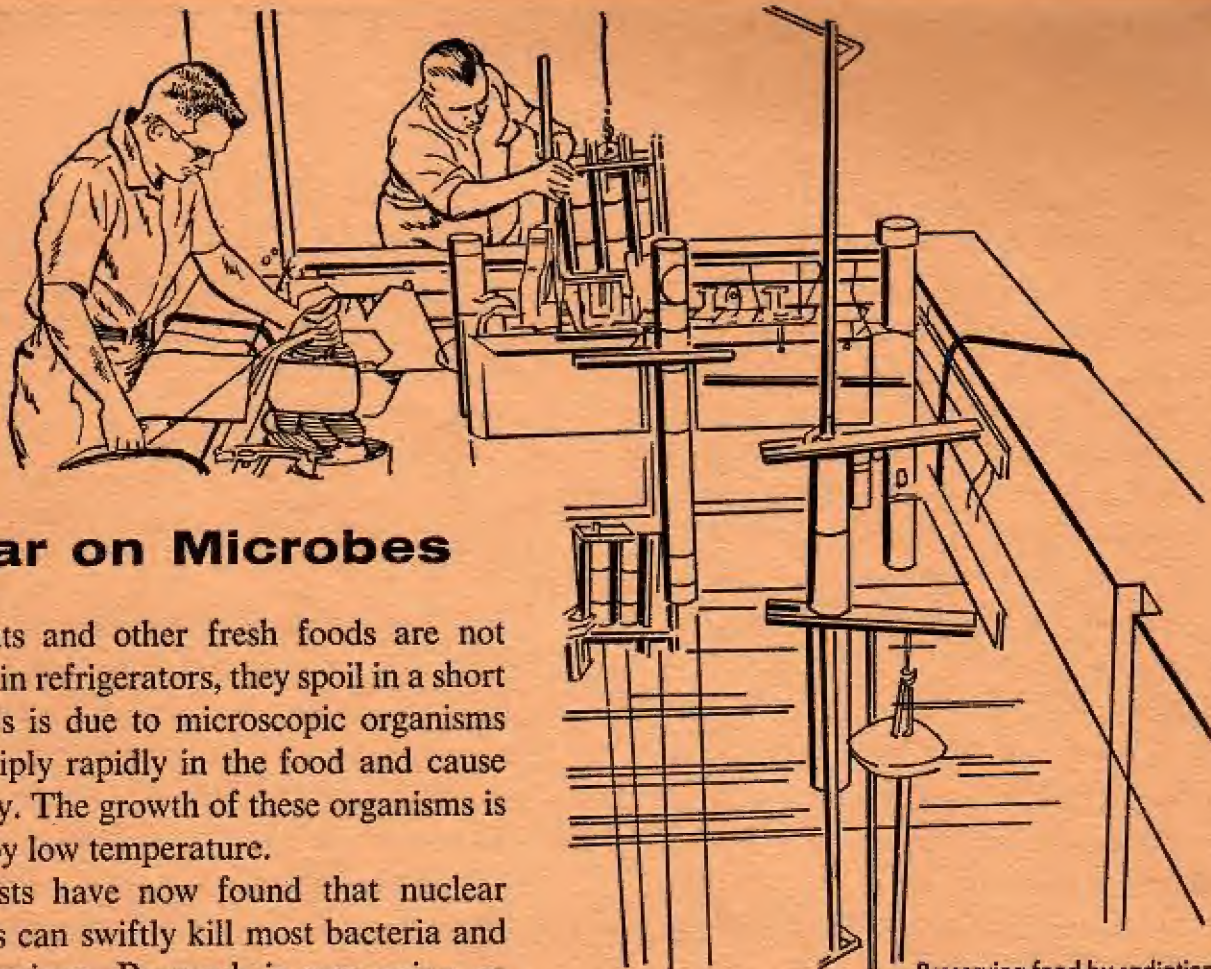
ones. New dusts and sprays, containing radioisotopes that are harmless to animals and men, are being tested to wipe out insect pests.

A few thousand dollars' worth of radioisotopes in pesticides may someday wipe out insects that now cause \$3,000,000,000 damage each year to our crops.

PLACE THE STAMP HERE

ATOMIC AGRICULTURE





## War on Microbes

If meats and other fresh foods are not kept cold in refrigerators, they spoil in a short time. This is due to microscopic organisms that multiply rapidly in the food and cause it to decay. The growth of these organisms is stopped by low temperature.

Scientists have now found that nuclear radiations can swiftly kill most bacteria and microorganisms. Research is now going on to produce completely sterilized foods by bathing them with rays from radioisotopes.

If the food product is immediately sealed in a plastic wrapping after the irradiation, it can last for weeks or months without spoiling, even without refrigeration. It cannot decay

Preserving food by radiation

because there is not even one single microbe left on the food.

However, the radioactive rays cause discoloration of the food, and a change in its taste. The researchers must keep experimenting until they eliminate these problems. But the day may come when we can keep fresh meat, vegetables, butter, and other perishable foods on our shelves instead of in refrigerators.

Nuclear radiations are also being used to sterilize manufactured products, such as leather goods, that are attacked by fungi or molds. Woolen goods can be mothproofed by atomic rays.

Radioisotopes and their powerful radiations are being used in many ways against our tiny, unseen enemies of the microscopic world.





## Atoms Aid Chemistry

In all kinds of chemical industries, radiations from radioisotopes are proving valuable aids. The same particles that can split atoms can also split molecules, which are groups of atoms, in the tanks or vats of chemicals.

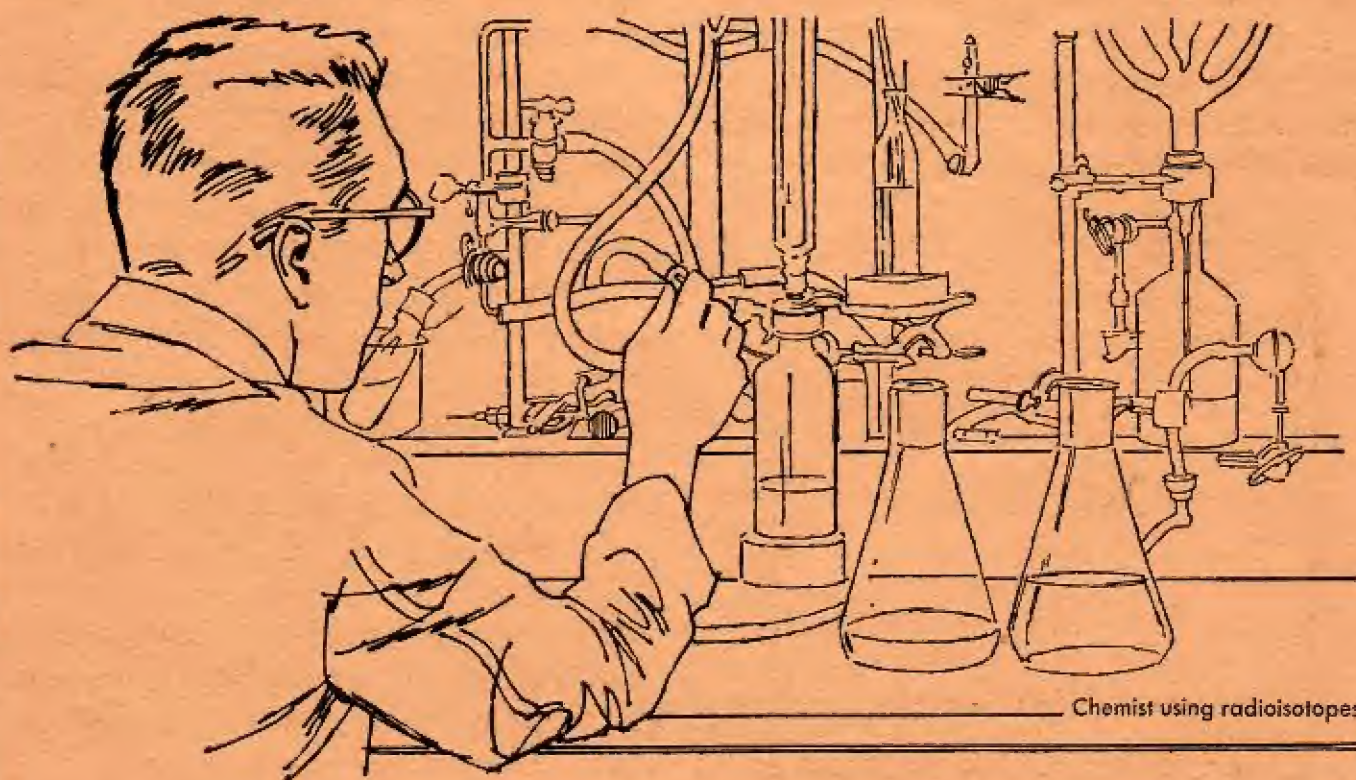
In oil refineries, the rays are used to speed up the "cracking," or separation, of crude oil into refined gasolines.

Manufacturers of drugs and medicines are using radioactive tracers to find out about the structure of a complicated molecule of a drug. For instance, if the molecule contains carbon atoms, they substitute atoms of radio-carbon in it. Then they can find out just where the carbon atoms go in the structure of the molecule. Once they have a "map" of the drug's molecule, they can make the drug in the laboratory instead of getting it from plants or animals.

Radioisotopes are helping chemists make certain chemical reactions that were impossible before. For example, a chemical re-

action may have required great heat to keep it going. This heat, however, would break down and destroy certain unstable chemicals and would ruin the whole reaction. Now, atomic rays may make some chemical reactions start even in a cold solution.

Radioisotopes are now used to make permanent auto paints, to waterproof leather, to turn sawdust into cattle food, to make synthetic rubber, and to create new plastics.



Chemist using radioisotopes



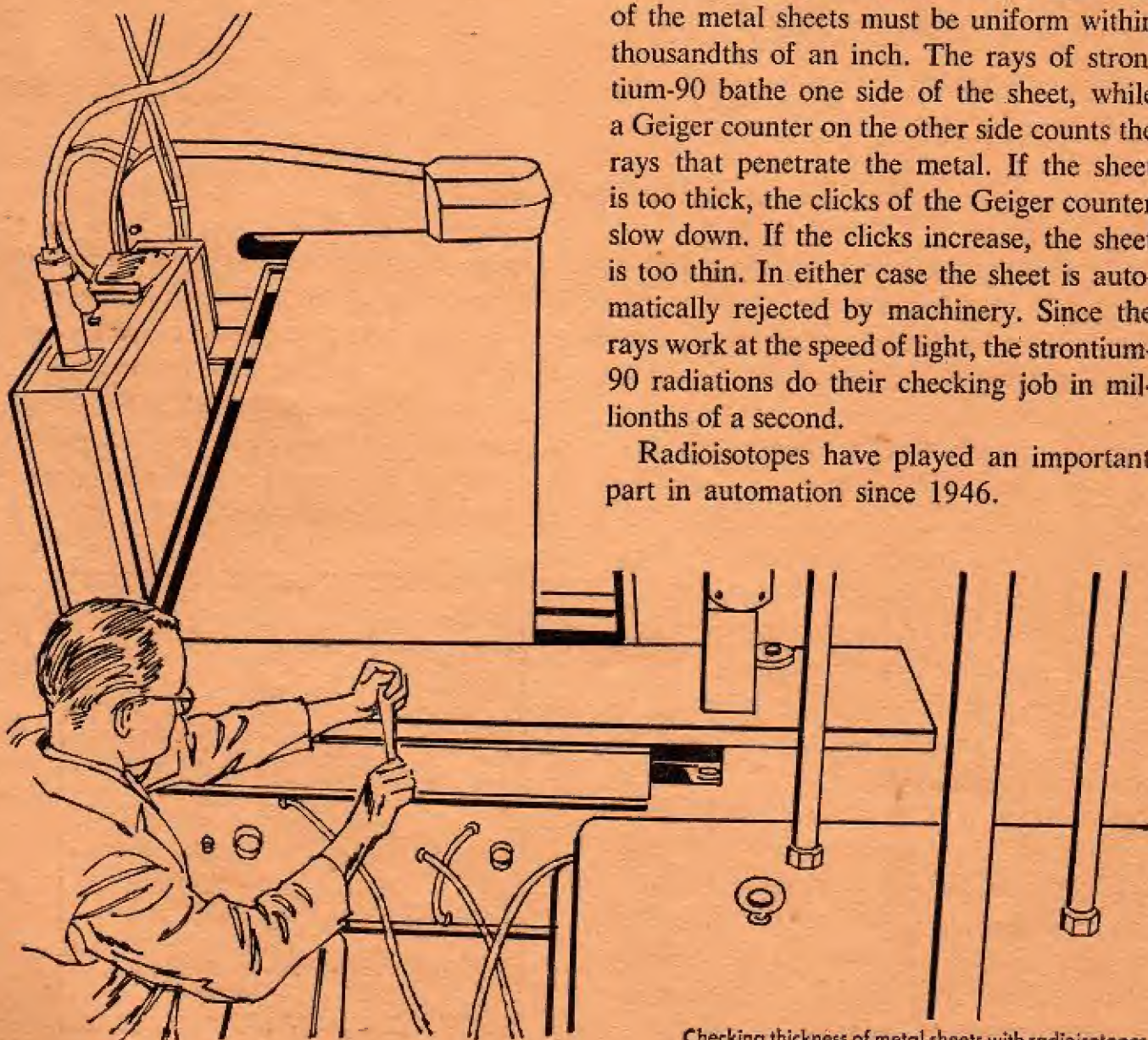
## Atomic Checkers

Automation started many years ago, with the photoelectric eye. This electronic tube could scan and sort things according to size or color in split seconds. This rapid sorting helped speed up manufacturing processes.

Now the radioisotope is replacing the photoelectric tube. The radioisotope requires no electricity and gives off rays for many years. Strontium-90, for instance, has a half-life of 28 years.

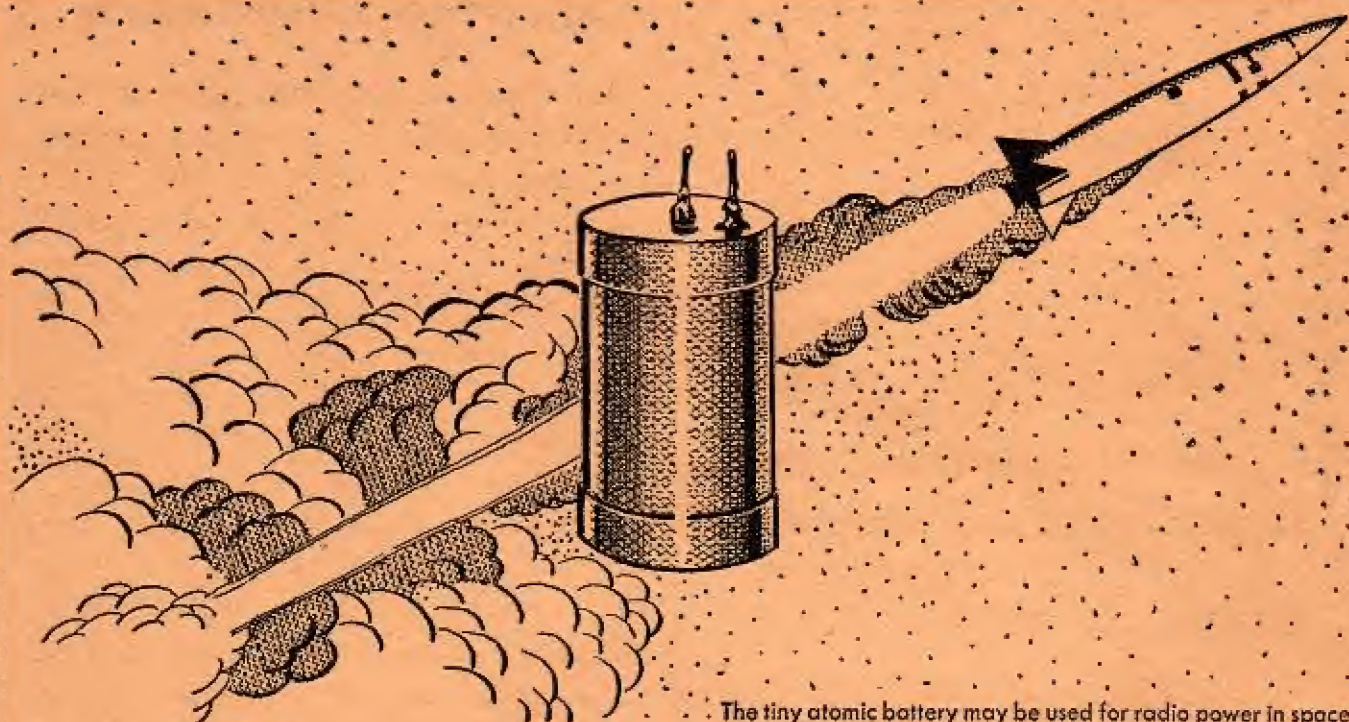
Strontium-90 is used in many ways. When metals are made in sheet form, the thickness of the metal sheets must be uniform within thousandths of an inch. The rays of strontium-90 bathe one side of the sheet, while a Geiger counter on the other side counts the rays that penetrate the metal. If the sheet is too thick, the clicks of the Geiger counter slow down. If the clicks increase, the sheet is too thin. In either case the sheet is automatically rejected by machinery. Since the rays work at the speed of light, the strontium-90 radiations do their checking job in millionths of a second.

Radioisotopes have played an important part in automation since 1946.



Checking thickness of metal sheets with radioisotopes





The tiny atomic battery may be used for radio power in space.

## The Atomic Battery

The atomic battery was invented in 1958. An ordinary battery is very heavy; the new atomic battery weighs less than a pound. The atomic battery also gives a much stronger current for a longer time.

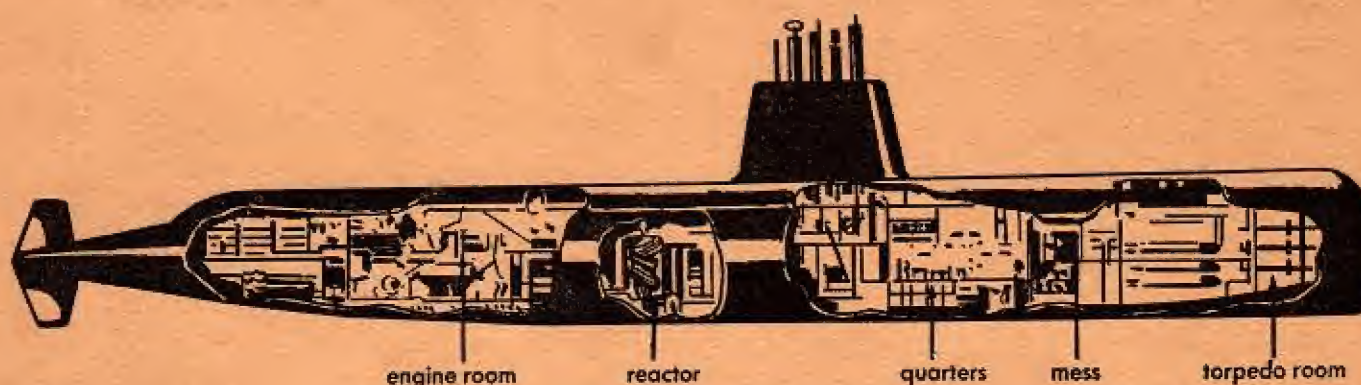
A small amount of the radioisotope cerium-144 makes the atomic battery work. As the unstable radiocerium atoms break down, they shoot out streams of electrons. And, electrons in motion make electric current. One atomic battery furnishes more electricity than dozens of ordinary batteries.

The first cerium batteries may be used in the space program. They will furnish radio power for planetary probes, such as missiles sent to Venus and Mars. Ordinary batteries would burn out during the long trips through space. But one small, light cerium battery can keep producing electricity for from five to nine months. Cerium-144 has a half-life of 290 days. During that time, its power will be reduced by only one half.

A new way of producing atomic electricity was discovered in 1959. A device placed in the core of a reactor produced electricity by using the core's heat directly. So far only a feeble current has been made this way. But if the process is improved, it will eliminate the clumsy and expensive ways of using atom-heated steam to make electricity.







Cross section of the Nautilus

## The First Atomic Engine

Years ago, the AEC began thinking about building atomic engines to run large vehicles, such as trains, planes, or ships. The problem was how to make the engines small and light enough to be carried by such vehicles. Atomic reactors for electrical power plants stand on the ground and are never moved, so they can be of any size or weight. But an atomic engine cannot be too heavy or too big.

The problem was finally solved and, in January, 1955, the first atomic submarine, the Nautilus, was launched. It immediately broke all submarine records by staying submerged for 84 hours. During this time it traveled 1,300 miles.

Other submarines need oxygen to burn the oil in their Diesel engines, and must, therefore, surface every few hours to take in a new supply of air. The atomic engine needs no oxygen for its fissioning fuel. One charge of uranium will drive it for over a year, and will take it at least 66,000 miles. The atomic submarine has to surface only when its crew runs out of food or tanked air.

The Nautilus' atomic motor was the first engine in the history of the world to run with a fuel which was not produced by the sun. Coal, oil, and all other previously used fuels were created by the sun's heat through various chemical processes. But the sun did not produce uranium, the most powerful fuel of all. The atomic submarine's engine has enough horsepower to make electricity for a city of 20,000 people.





## Atomic Submarine Records

Since the Nautilus, more atomic submarines have been launched—Seawolf, Skate, Skipjack, Sea-dragon, Triton, Halibut, Tullibee, and George Washington. Twenty-six more are under construction and 110 have been commissioned to be built.

The atomic submarines now in use have made many records. In October, 1958, the Seawolf surfaced after being submerged for sixty days, during which time it traveled 14,500 miles. Not once in two months did the submarine rise to the surface.

The Skipjack, the speediest ship of its weight, is able to go at least 45 miles per hour underwater, which is faster than any surface warship can go. The Skipjack can turn and dive underwater with almost the same ease that a jet plane does in the air.

The George Washington, finished in June, 1959, is the first American submarine that can launch missiles from under water. It can hurl a Polaris IRBM missile, weighing 15 tons, up through 100 feet of water to 70 feet above the surface. From there the missile's rocket engine can propel it through the air for a distance of 1,500 miles.

But the Nautilus itself has also continued



to make headlines. In 1958, it crossed under the North Pole and its floating icecap. The total submerged distance the Nautilus traveled, from offshore Alaska to offshore Greenland, was over 3,000 miles. Its crew obtained much new information. They found that the polar ice sheet is, on the average, 12 feet thick directly under the North Pole, and that the Arctic Ocean is 13,410 feet deep.

Then, in August of 1958, the Nautilus crossed the Atlantic in six days and twelve hours. It was submerged all the way, except for brief surfacings to radio home its progress.





## Nuclear Ships

The success of the atomic submarines made the United States Navy change its future plans. It started to convert many of its surface fleet's engines to atomic power, too. In time, the United States will have a nuclear navy.

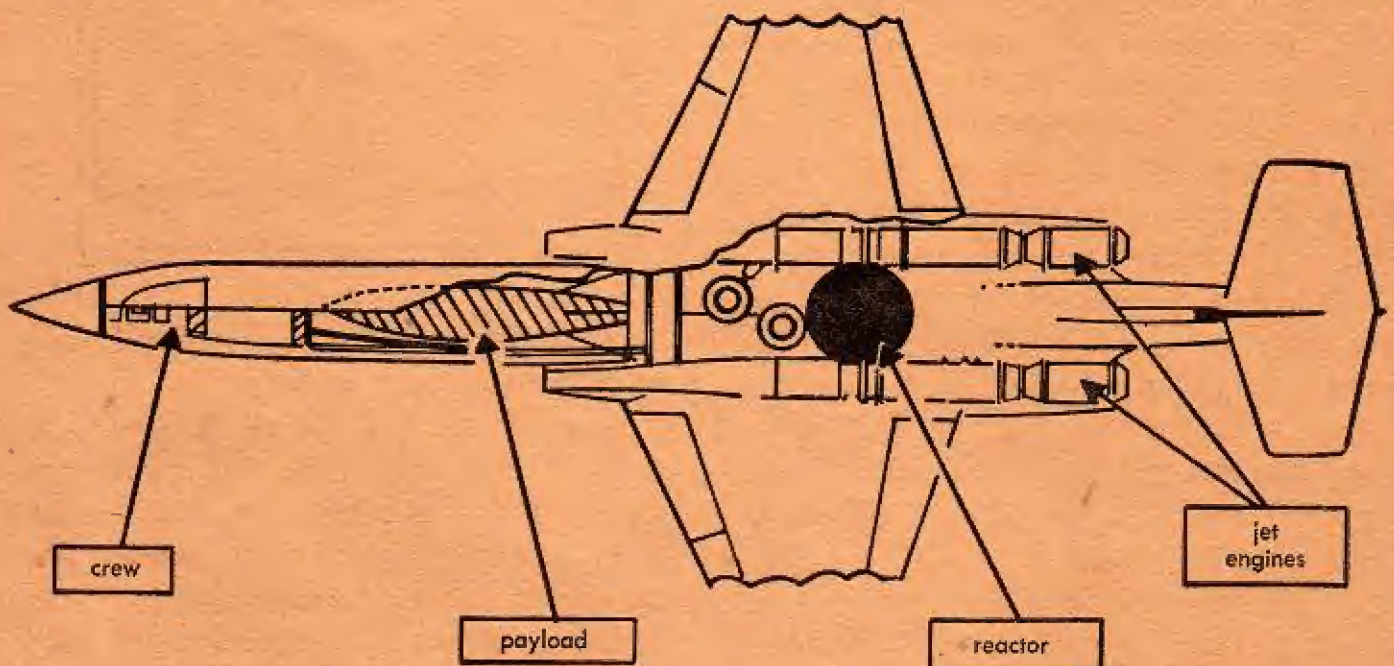
Any unit of this future navy will then be able to travel for a long time without needing to refuel. All the room formerly needed for thousands of tons of coal or barrels of oil can be used to provide more space for ammunition or for the crew. The ships' speed will be almost twice as fast as pre-atomic warships. Their reactors can supply any amount of heat and power needed.

Eventually, there may be nuclear-powered aircraft too. Probably only the largest bombers and cargo planes will be able to use atomic engines, which, because of their heavy shielding, will always weigh many tons.



The United States also built the world's first atomic merchant ship, the N.S. Savannah (N.S. stands for "Nuclear Ship"), which was launched in 1959.

Britain and other oil-importing nations are planning giant atomic oil-tanker ships, each of which will be able to carry a cargo weighing over 100,000 tons.



Atomic-powered aircraft of the future





Underground atomic blast could expose ores for easy mining.

## Project Plowshare

Other ways of using peacetime atomic power are planned by the AEC under Project Plowshare. This project was begun in September, 1957, when the first atomic bomb was exploded underground at a Nevada test site. The bomb was a comparatively small one of 1.7 kilotons power, equal to 1,700 tons of TNT. It was exploded 790 feet below the ground, and it did an amazing job. It loosened over a half million tons of solid rock, and crushed this rock into rubble.

The AEC immediately saw how such power could be used in the future. Many beds of ore, for instance, lie deep under solid rock, and are too hard to reach by ordinary drilling and mining. But underground atomic blasts could crush the rock and expose the ore for easy mining.

Then, there are many large deposits of oil-bearing shale in this country. The oil is soaked in the porous shale and cannot be pumped out. Atomic explosions can pulverize the shale and free the oil which may



form a large underground pool. It will then be possible to pump out the oil.

Another plan is to use atomic bombs to widen narrow harbors. Shipping can then be increased to those ports. Also, it is possible that winter ice can be shattered to keep northern seaports ice-free all year.

Atomic bombs may also be used to open water wells under arid lands. In the future, Project Plowshare will use the atom's power to benefit civilization in many ways.



## Atomic Rockets

Intercontinental ballistic missiles, or ICBMs, can now carry atomic warheads, but they are still propelled by ordinary chemical fuels. However, atomic engines for rockets are being planned by nuclear scientists.

The best chemical fuels used today give rockets a thrust of around 500,000 pounds. Atomic rockets would be much more powerful, with thrusts up to 10,000,000 pounds.

The atomic engine could not propel the rocket directly. It does not produce high-speed jets of gases as do chemical fuels. But the tremendous heat of the atomic reactor will turn water into steam which could blast out of the rocket's tubes. Or, liquefied gases, like hydrogen and helium, could be made to expand with heat and form the rocket blasts.

Whatever system is used, the reactor will furnish unlimited, continuous power. Chemical rockets all burn out in a short time. Atomic rockets could keep blasting for hours, and building up to far greater speeds.

The first nuclear rocket engine was tested in Nevada by the AEC in July, 1959. It was named the Kiwi, after a New Zealand bird that cannot fly. This test engine did not fly either. The engine was solidly bolted to a



Rockets may be atomic-powered in the future.

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TESTING ATOMIC ROCKET MOTOR

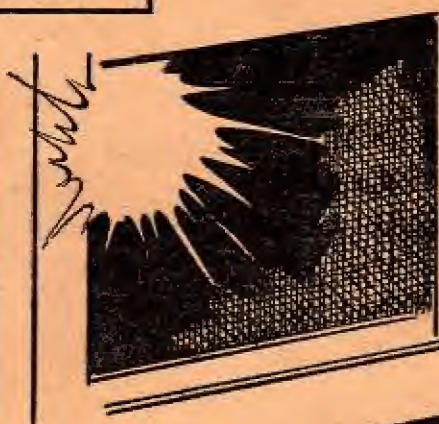
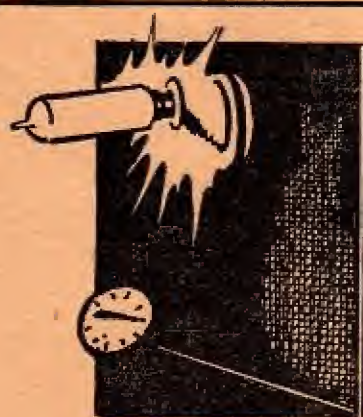
railroad car and was only ground-tested for its performance. The reactor was small and light enough for use in rockets. It heated up hydrogen gas to make the blasts. The test was very successful.

More tests and improvements will be needed, but someday an atomic rocket will take off into space.





Studying ion-drive for use in rockets



## Atoms in the Space Program

Atomic rockets will be especially important in the space program. They are being tested under Project Rover. Nuclear missiles will be able to hurl giant satellites into orbit around the earth. These satellites will be filled with instruments weighing more than twenty-five tons.

Atomic rockets also will be able to lift into orbit big cargoes for building the manned space stations of the future.

Nuclear engines will also be valuable for sending huge space ships to the moon and to the other planets. Thousands of tons of chemical fuels would be needed for such an interplanetary trip. The atomic rocket, on the other hand, would require only a 100-pound core of fissioning uranium, plus tanks

of a light-weight propellant like hydrogen or helium, to make such a trip.

Scientists also envision another way in which atomic power can drive space ships at speeds close to that of light itself, or 186,300 miles per second. This will be called the "Ion Drive." Ions, or electrified particles, will come out of the atomic reactor to form the blasts. The thrusts will be comparatively low-powered but steady. This continuous acceleration, or gain in speed, will gradually build up to such great speeds that the space ship could reach the farthest planet, Pluto, four billion miles from the Earth, in a few days. The atomic ion rockets may even someday send space ships to the nearest star, 25,000,000,000,000 miles away.



## Atom Wonders Ahead

The atomic energy wonders of today may be nothing compared to the future wonders that scientists will pry out of the atom. Each of the subatomic particles, of which twenty-one or more are known, may lead to a great discovery, just as the neutron did.

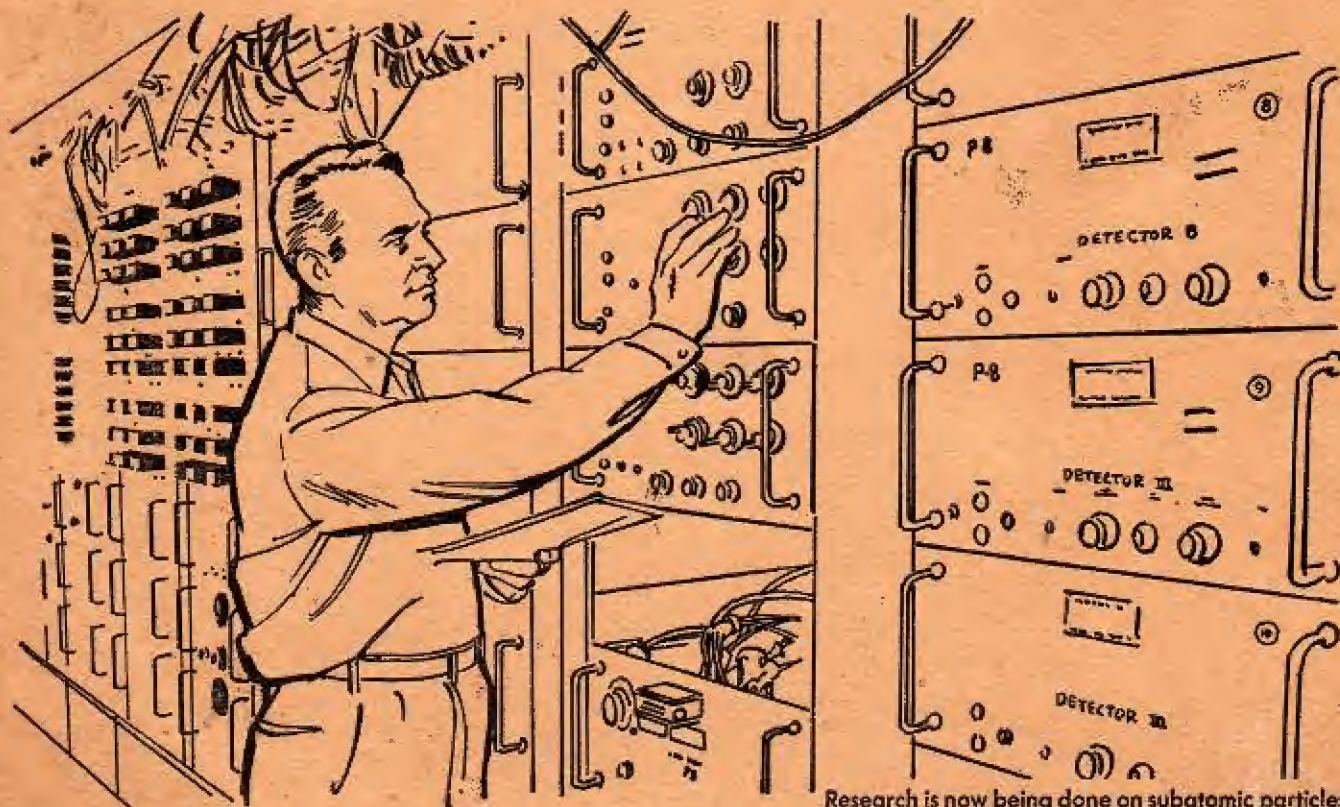
For instance, the neutrino, a particle produced in atomic reactions, is pure energy and has no weight. If these weightless particles can be harnessed, they might give us gravity-defying devices. Then the heaviest object could be made to float in the air like a feather. We can hardly imagine how the lack of weight would affect aircraft and rockets.

Strangest of all are the anti-matter particles now being studied. They seem to be a kind of "opposite" matter that does not exist in our universe except by accident. When anti-matter particles meet normal-matter particles, both are annihilated in a burst of energy far greater than that released by fission or fusion.



Is this a form of supernuclear energy that scientists may someday show us how to use?

Nobody knows yet. Nor does anyone know what other surprises will come out of the atom. They may be as startling to the world as the first atomic bomb which ushered us into the amazing Atomic Age.



Research is now being done on subatomic particles.





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### GOLDEN STAMP BOOKS

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 AND YESTERDAY  
 P-49 SEA SHELLS  
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 P-56 THE UNITED STATES  
 P-58 WILDLIER WONDERS  
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 P-62 SPACE WONDERS  
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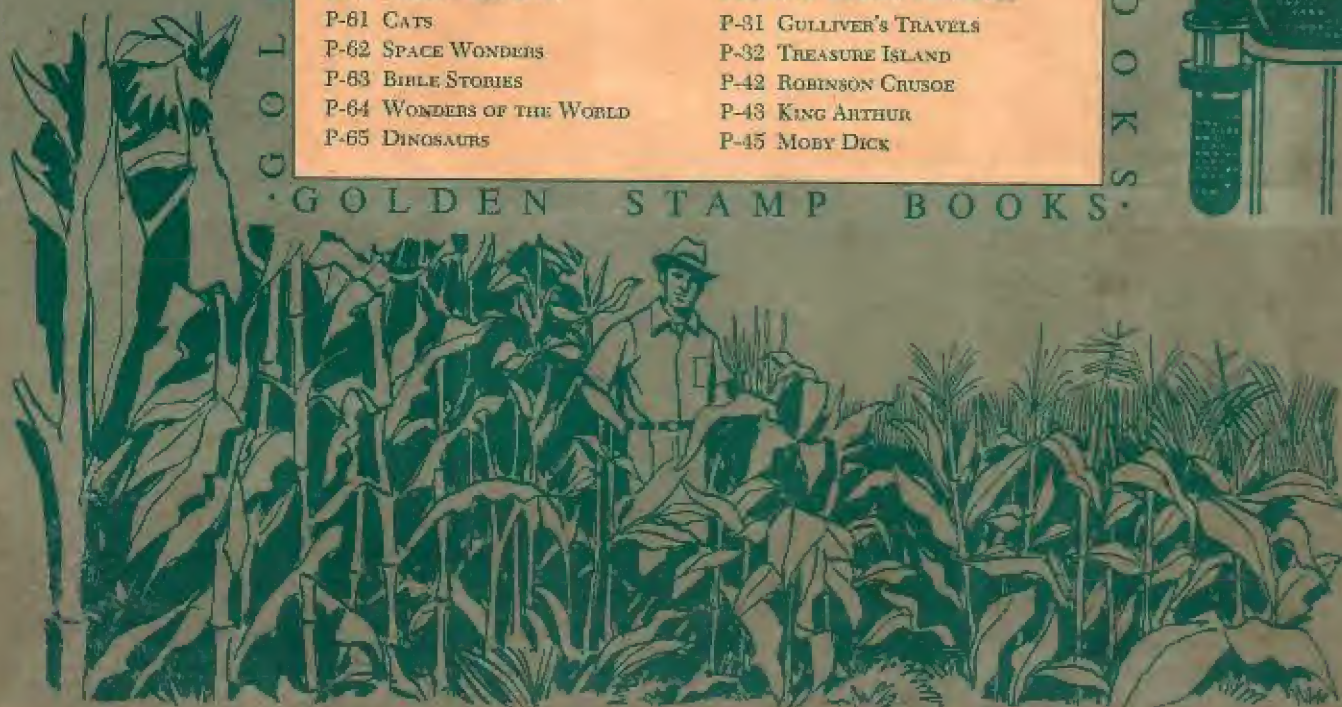
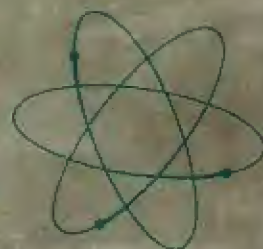
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 WD-7 ANIMALS OF AFRICA  
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 WD-9 SECRETS OF LIFE  
 WD-10 SLEEPING BEAUTY  
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$$E=mc^2$$







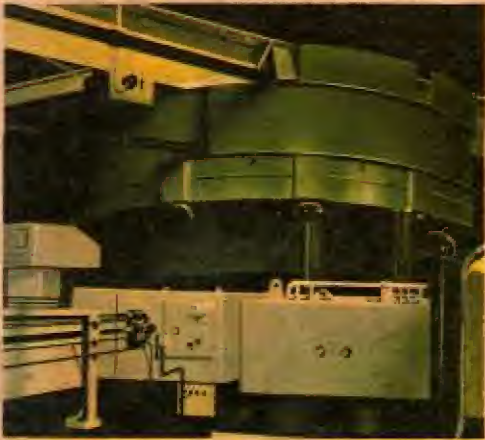
VAN DE GRAAFF ATOM SMASHER



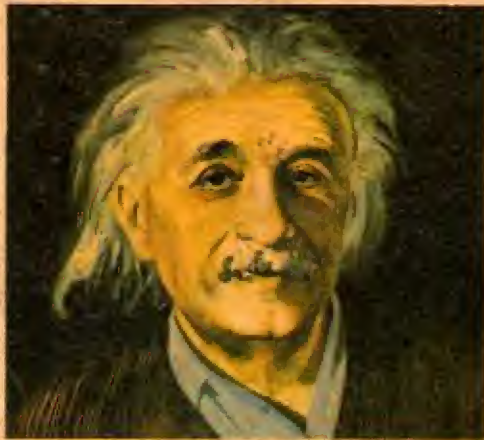
TESTING ATOMIC ROCKET MOTOR



ATOMIC-POWERED SPACESHIP



CYCLOTRON



ALBERT EINSTEIN



UNDERWATER HYDROGEN BOMB TEST



THE SEA IS A SOURCE OF HEAVY HYDROGEN



AN ATOMIC PILE



ATOMIC AGRICULTURE



SHIELDED ROBOT DEVICE



FUSION RELEASES MORE ENERGY THAN FISSION



STERILIZING FOOD BY RADIATIONS